The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2050-7

Targeted Training Activity: Predictability of Weather and Climate: Theory and Applications to Intraseasonal Variability

27 July - 7 August, 2009

Ensemble predictions at ECMWF: The seasonal scale and beyond

Franco Molteni

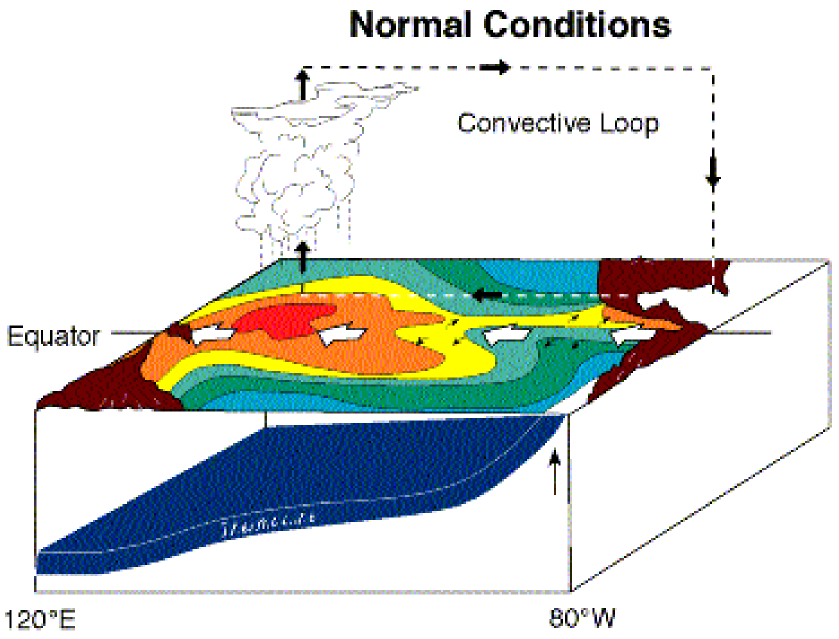
European Centre for Medium-Range Weather Forecasts
Reading
U.K.

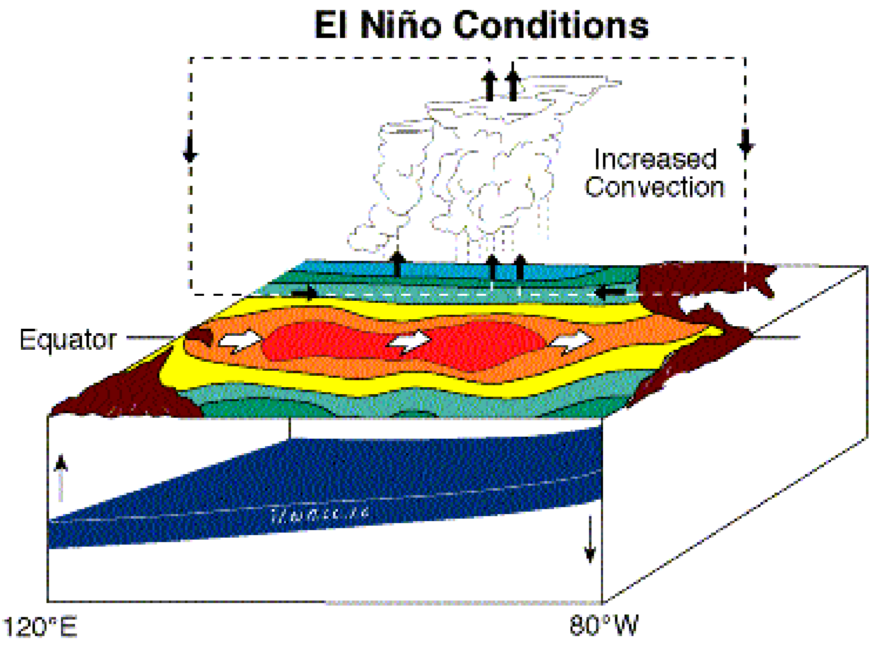
Ensemble predictions at ECMWF:
The seasonal scale and beyond

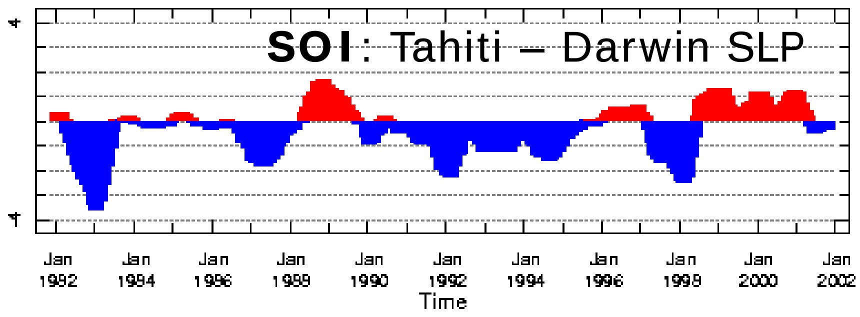
Franco Molteni and
the ECMWF Seasonal Forecast Section

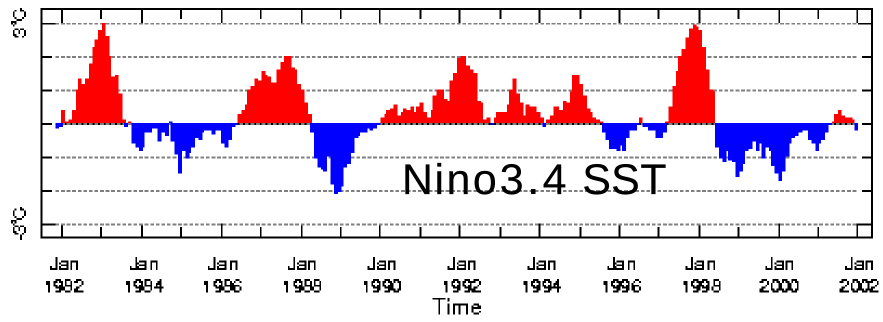
European Centre for Medium-Range Weather Forecasts, Reading, U.K.

The El Niño – Southern Oscillation (ENSO)





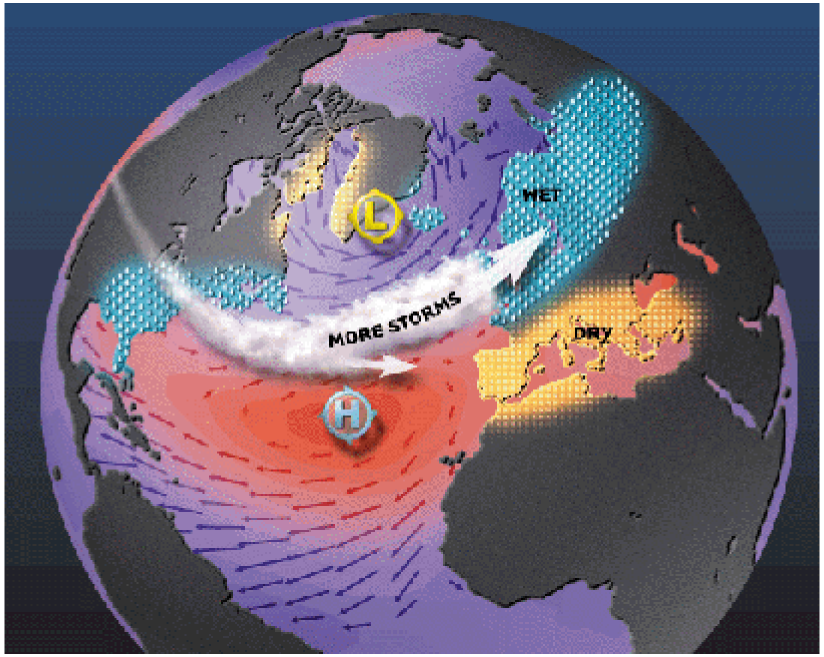




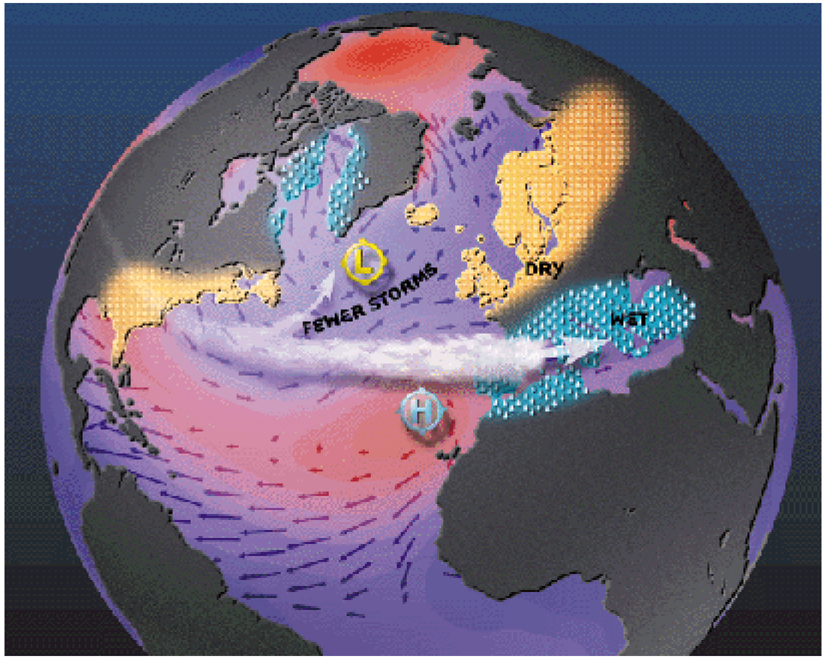
The North Atlantic Oscillation (NAO)

Walker and Bliss (1932)

Van Loon and Rogers (1978)



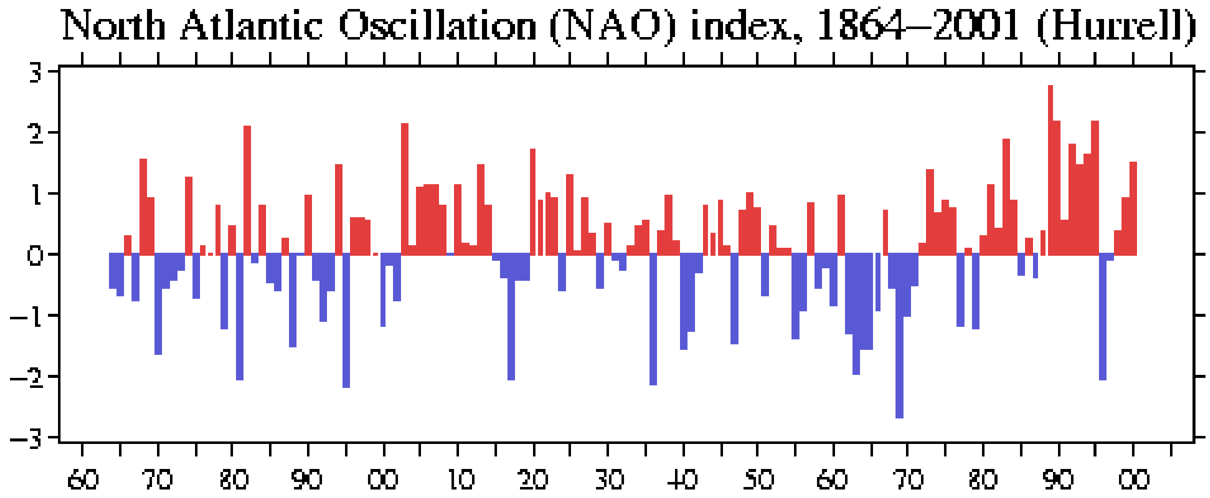
Positive NAO phase

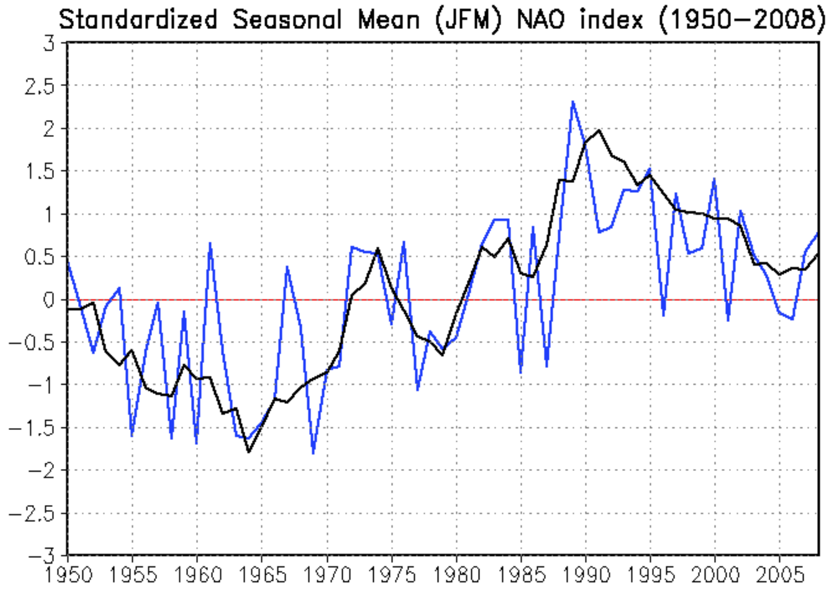


Negative NAO phase

Inter-decadal NAO variability

Stand. SLP index
Lisbon – Iceland
Dec.-March



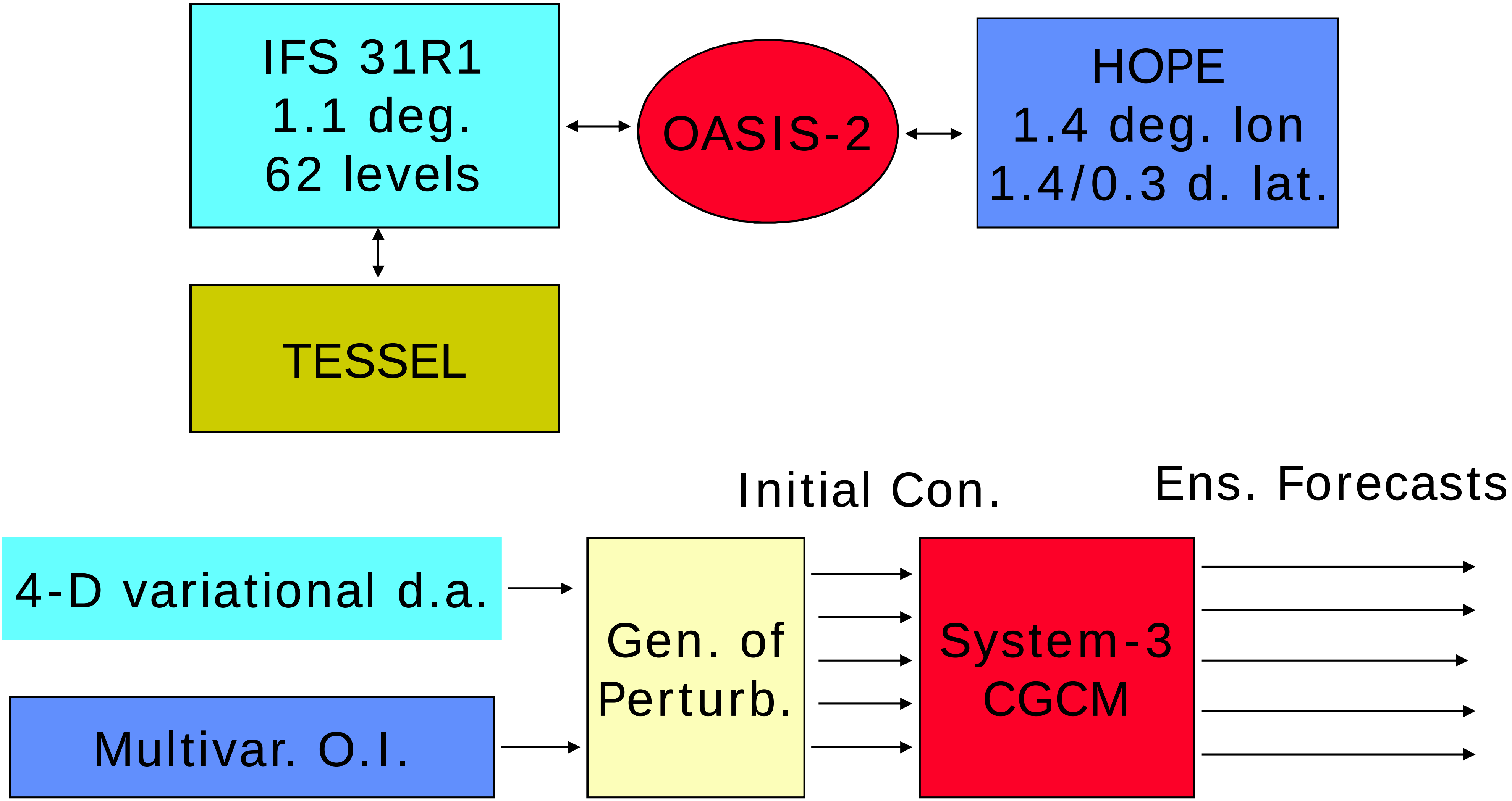


Rotated Principal Component
of 500 hPa height
Jan.-March

Challenges for seasonal to decadal predictions

1. The evolution of climate anomalies on seasonal to decadal scale depends on the evolution of the coupled ocean-atmosphere-land system.
2. Initial conditions for atmospheric, oceanic and land-surface variables have to be specified, together with estimates of uncertainties.
3. Inaccurate representation of interactions and feedbacks between atmosphere, ocean and land variability can lead to substantial differences between the observed and model climate.
4. The calibration (e.g. bias correction) and assessment of seasonal to decadal EPS requires the integration of the system from many different initial states, covering periods with variable concentrations of GHG and aerosols.

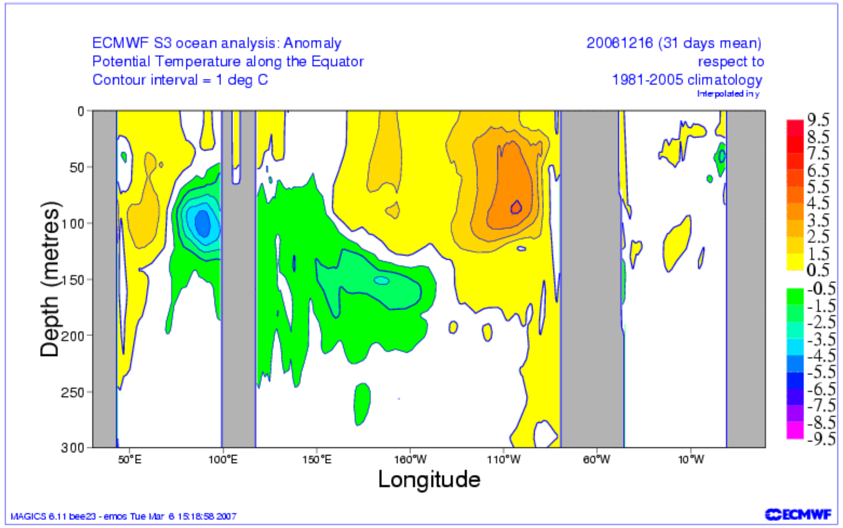
ECMWF Seasonal forecast system (Sys-3)

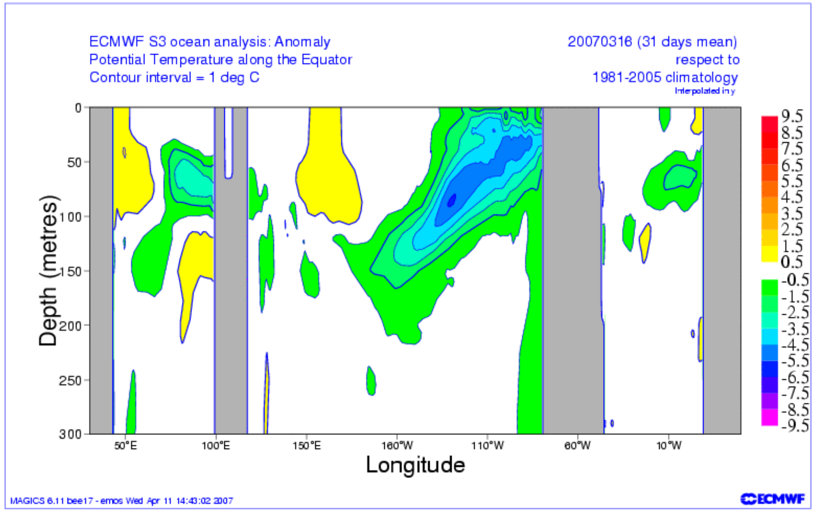


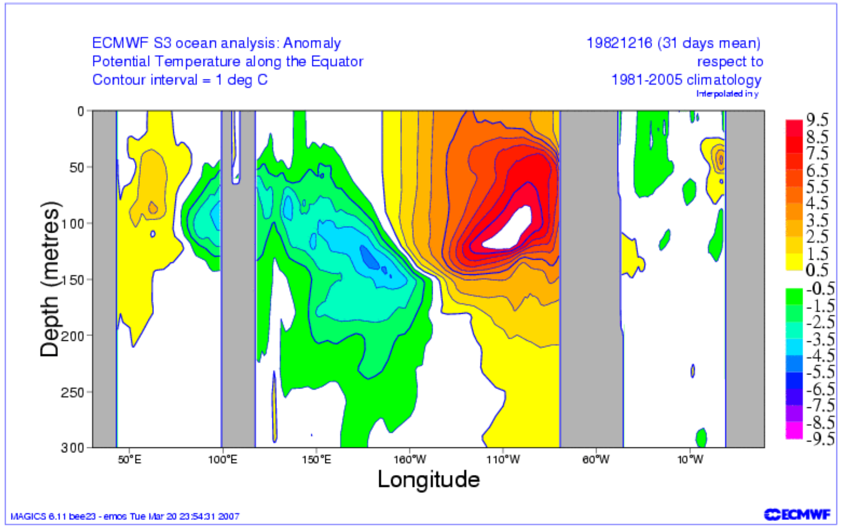
The seasonal forecast System-3 (implem. March 07)

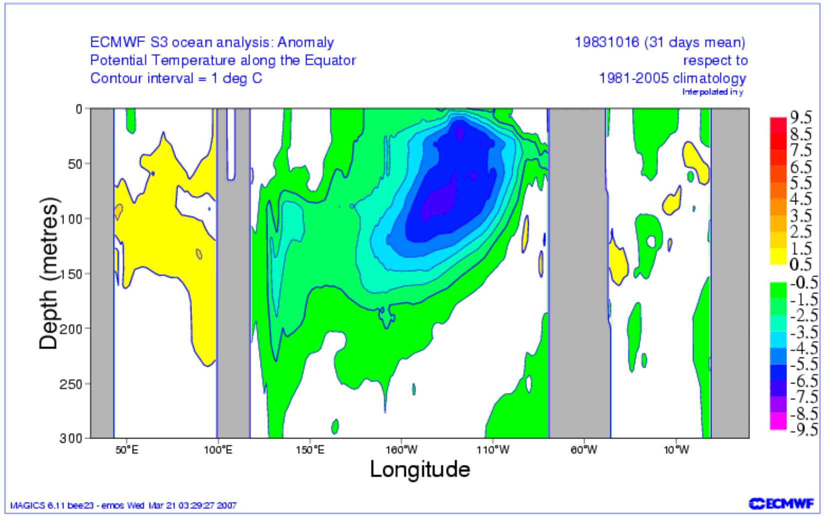
- COUPLED MODEL (IFS + OASIS2 + HOPE)
  - Recent cycle of atmospheric model (Cy31R1)
  - Atmospheric resolution TL159 and 62 levels
  - Time varying greenhouse gasses.
  - Includes ocean currents in wave model
- INITIALIZATION
  - Includes bias correction in ocean assimilation.
  - Includes assimilation of salinity and altimeter data.
  - ERA-40 data used to initialize ocean and atmosphere in hindcasts
  - Ocean reanalysis back to 1959, using ENACT/ENSEMBLES ocean data
- ENSEMBLE GENERATION
  - Extended range of back integrations: 11 members, 1981-2005.
  - Revised wind and SST perturbations.
  - Use EPS Singular Vector perturbations in atmospheric initial conditions.
- Forecasts extended to 7 months (to 13 months 4x per year).

Products from Sys-3: ocean reanalysis

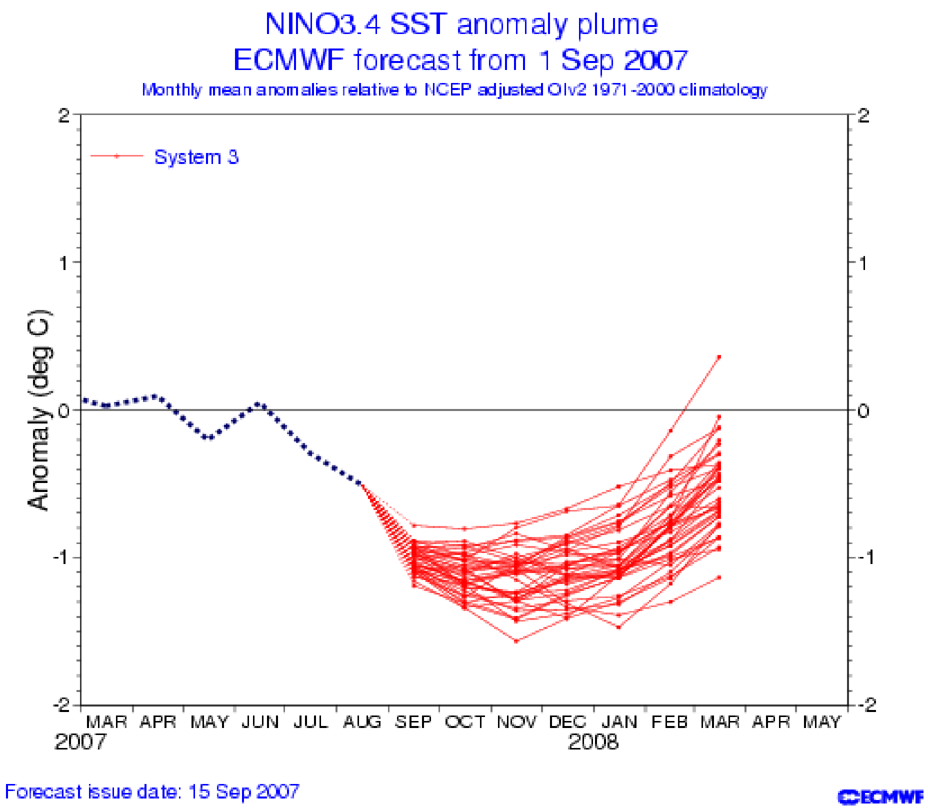


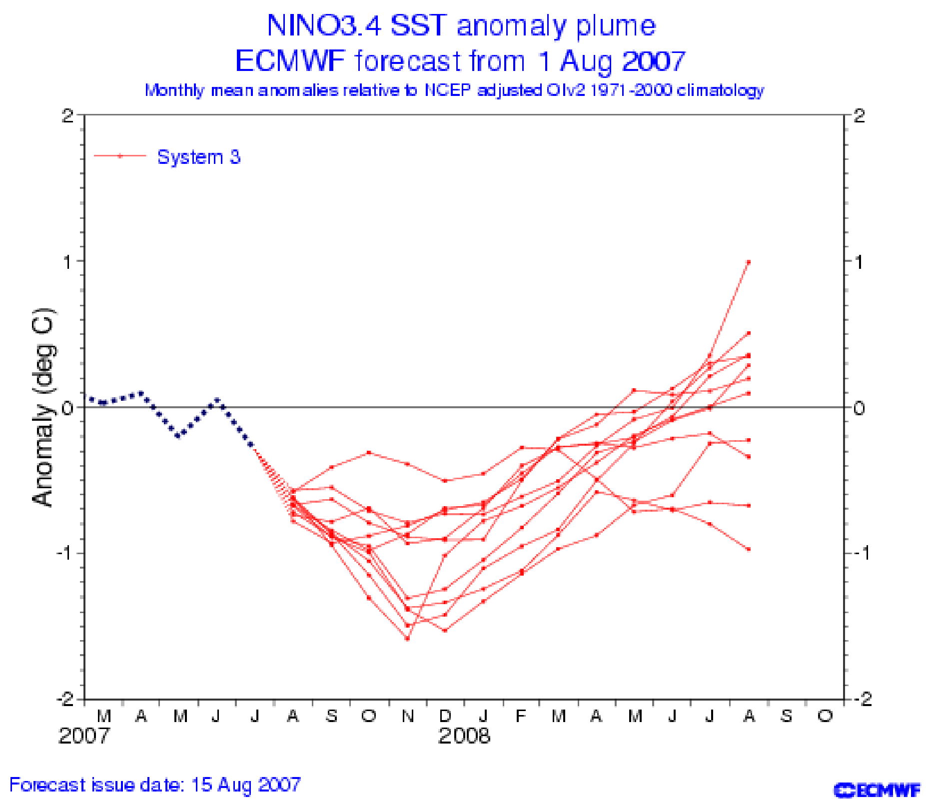




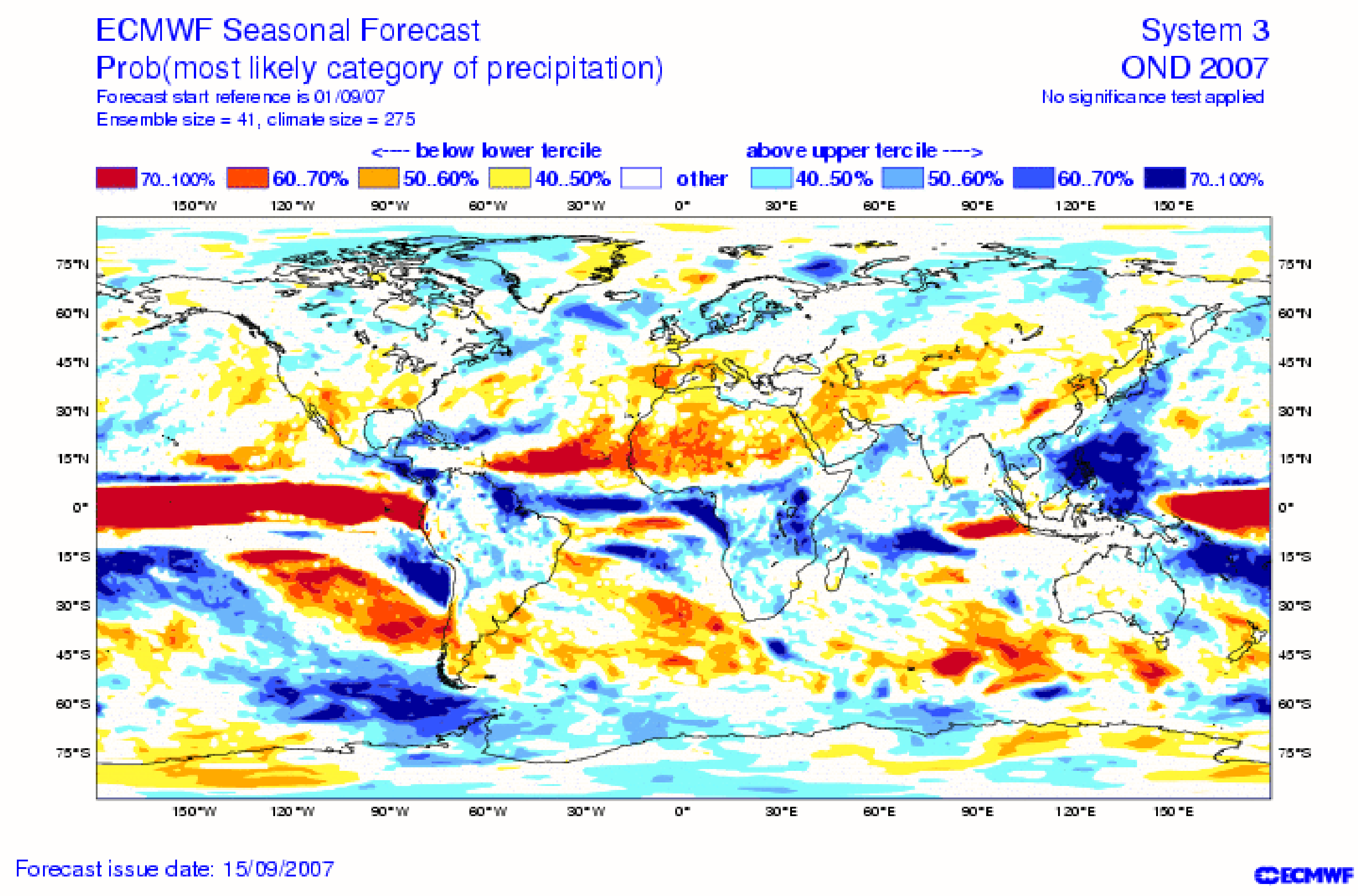


Products from Sys-3: “plumes” for El Nino indices

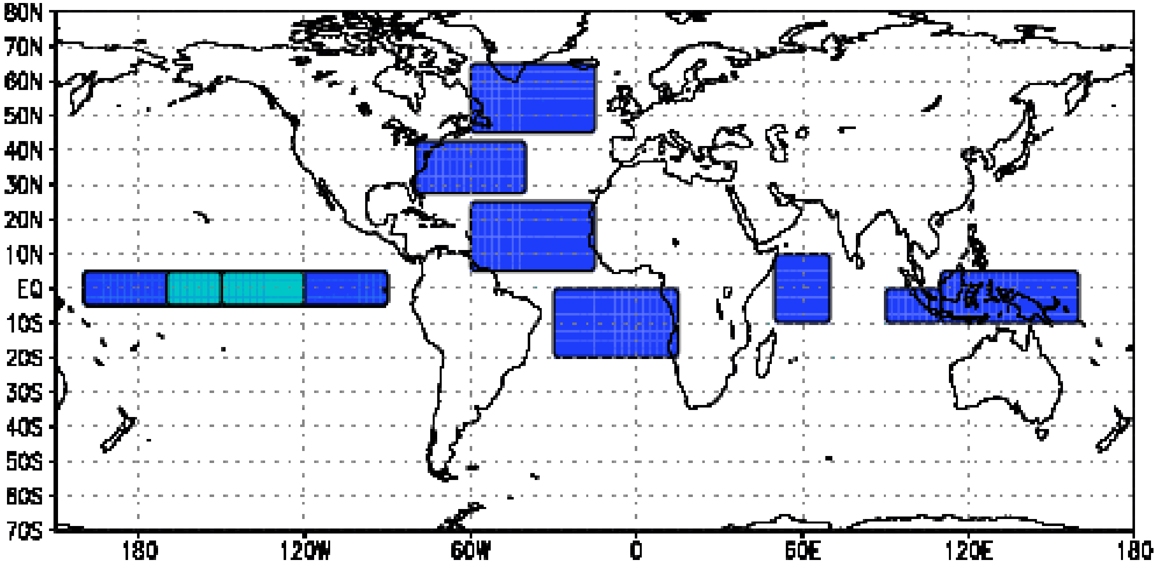


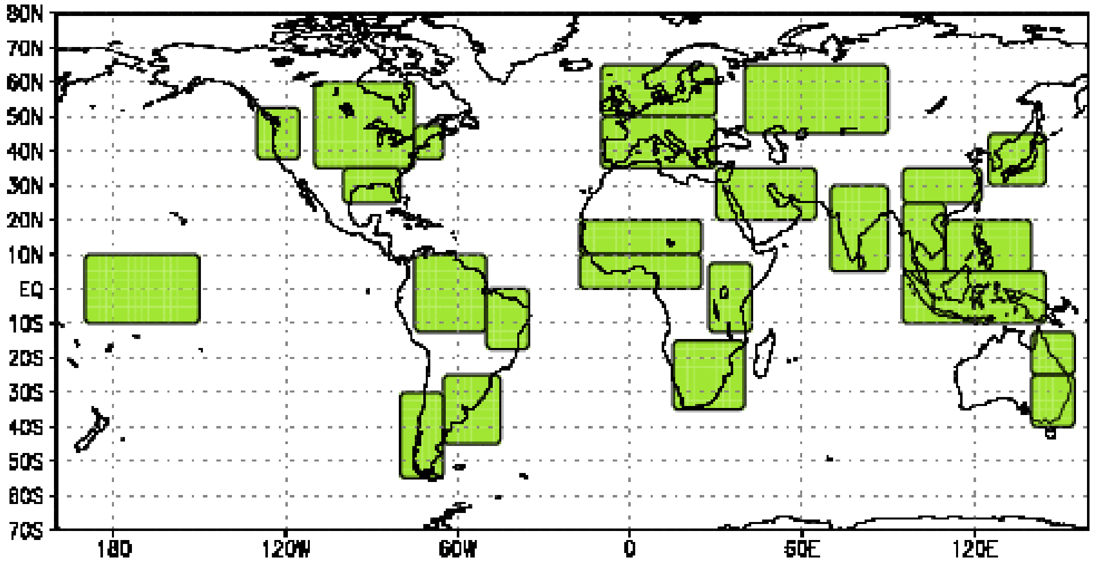


Products from Sys-3: 'tercile summary'

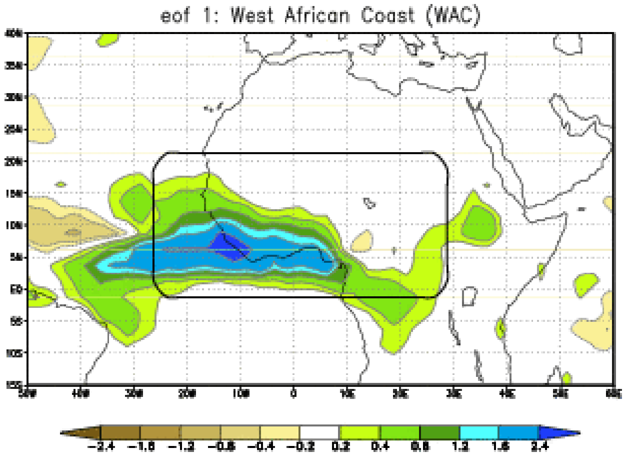


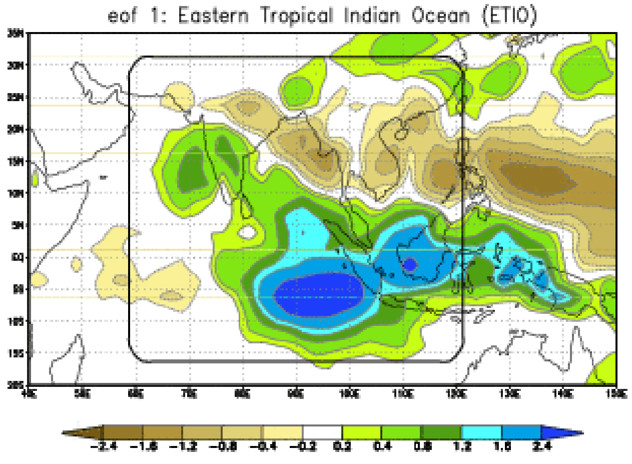
Climagrams: area-averages of SST, 2mT and rainfall

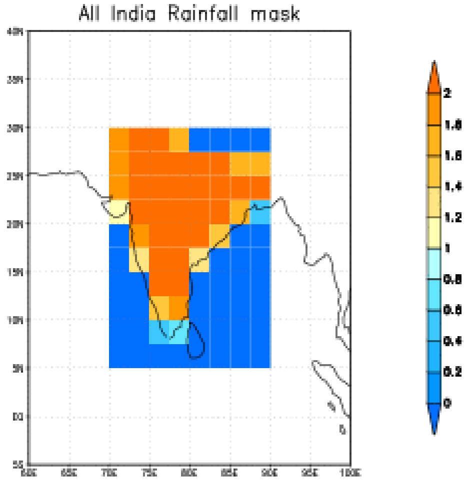


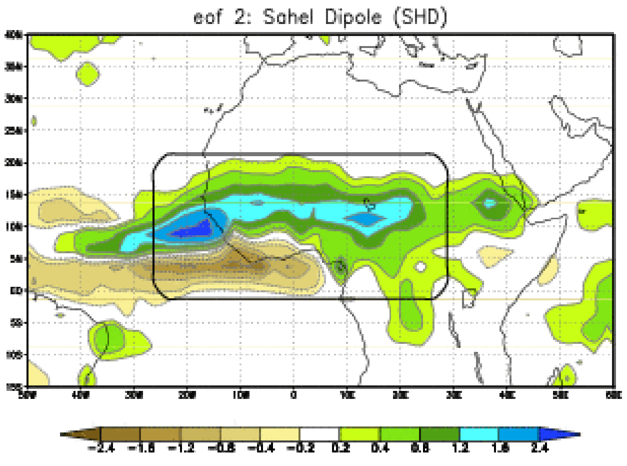


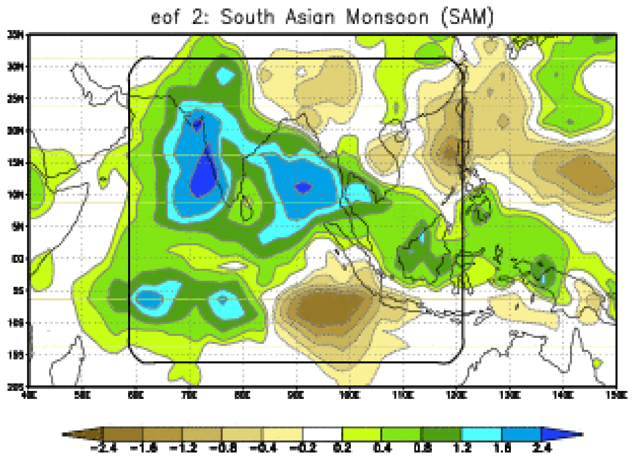
Climagrams :monsoon indices / teleconnections



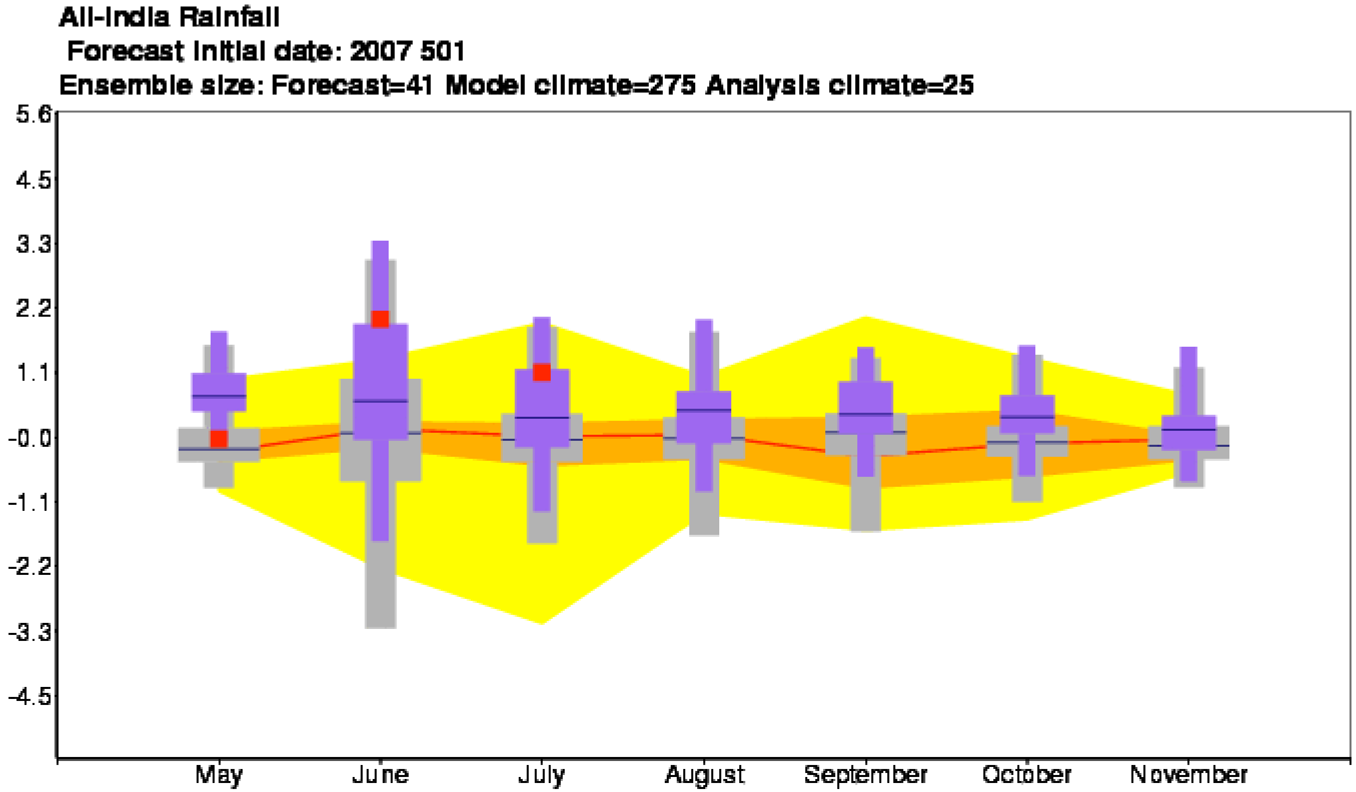






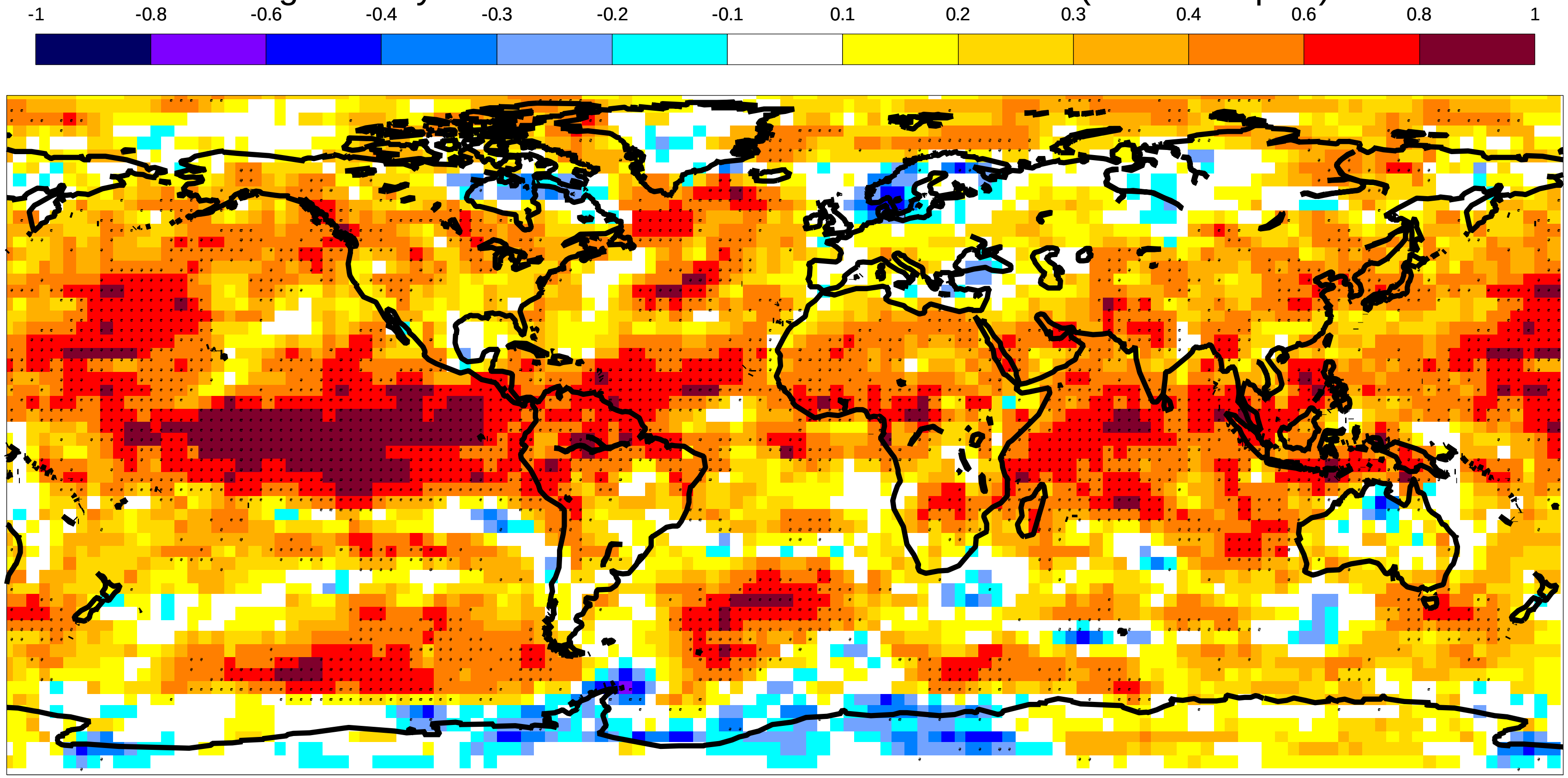


All India Rainfall: “climagram” from 1 May 2007



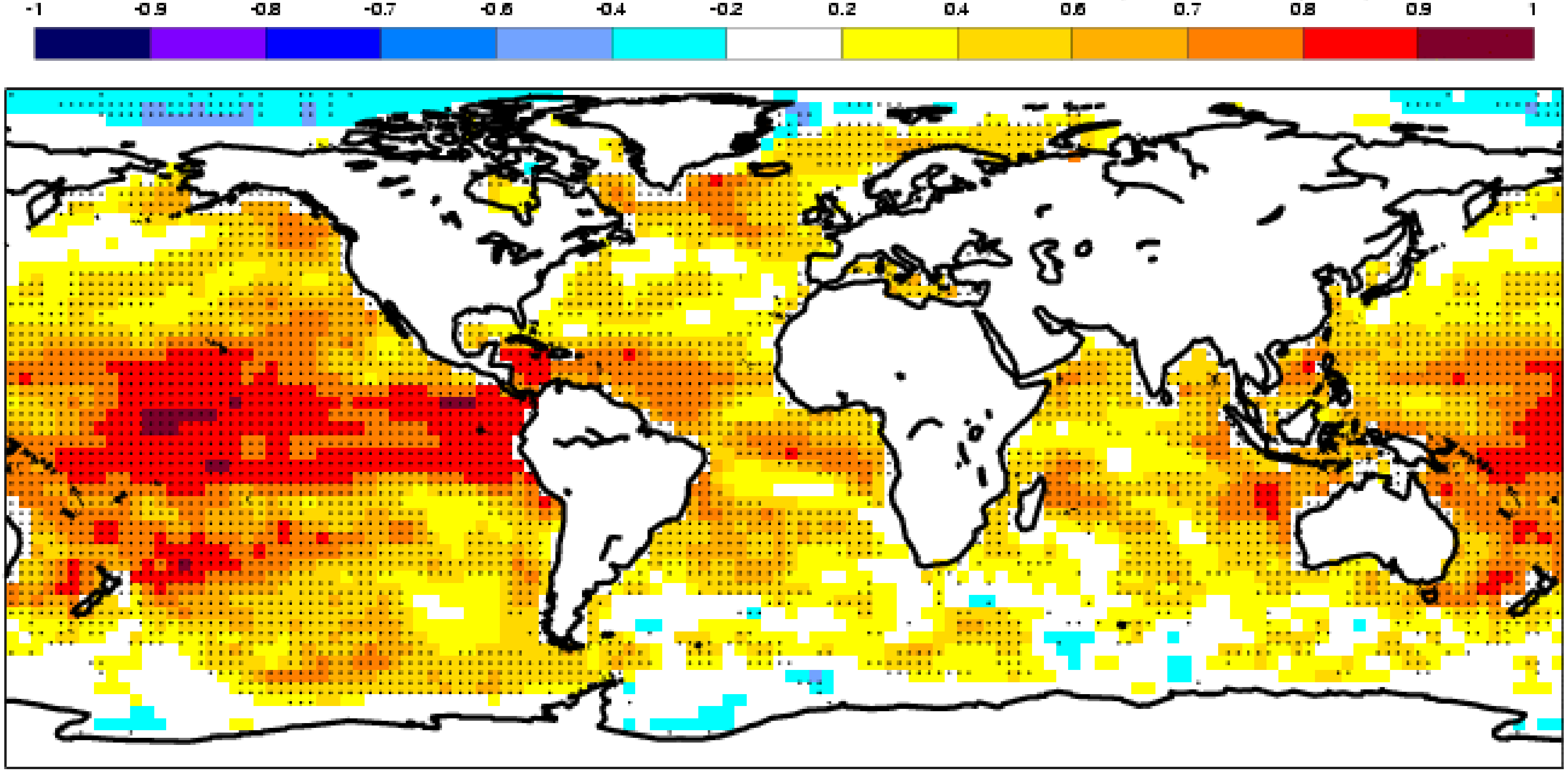
Verification for T_2m in DJF from 25-year hindcast set

ROC Skill Score for ECMWF with 11 ensemble members and 12 bins
Near-surface temperature anomalies above the upper tercile
Hindcast period 1981-2005 with start in November average over months 2 to 4
Threshold computed ranking the sample
Black dots for values significantly different from zero with 95% confidence (1000 samples)

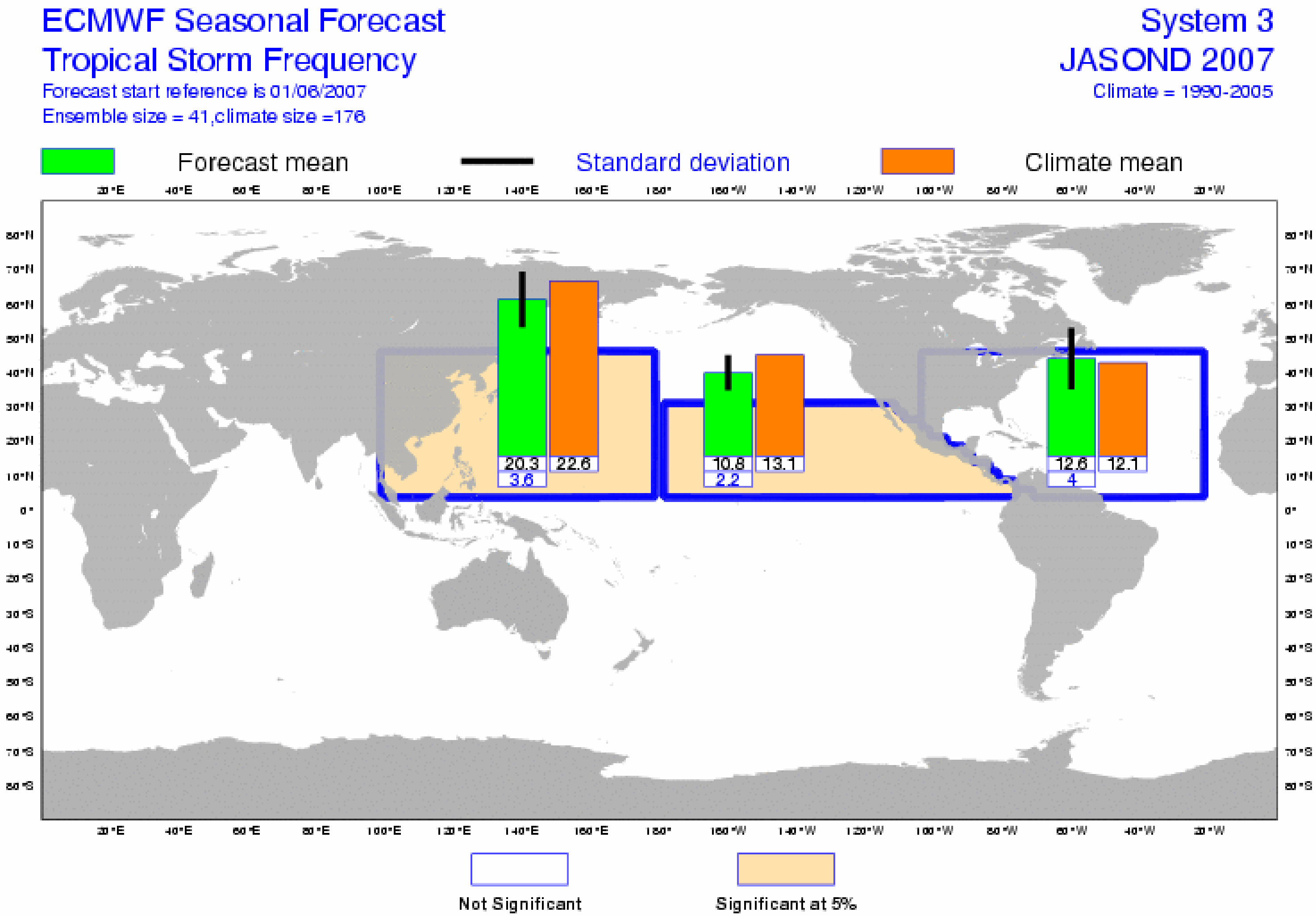


Verification for SST in JJA from 25-year hindcast set

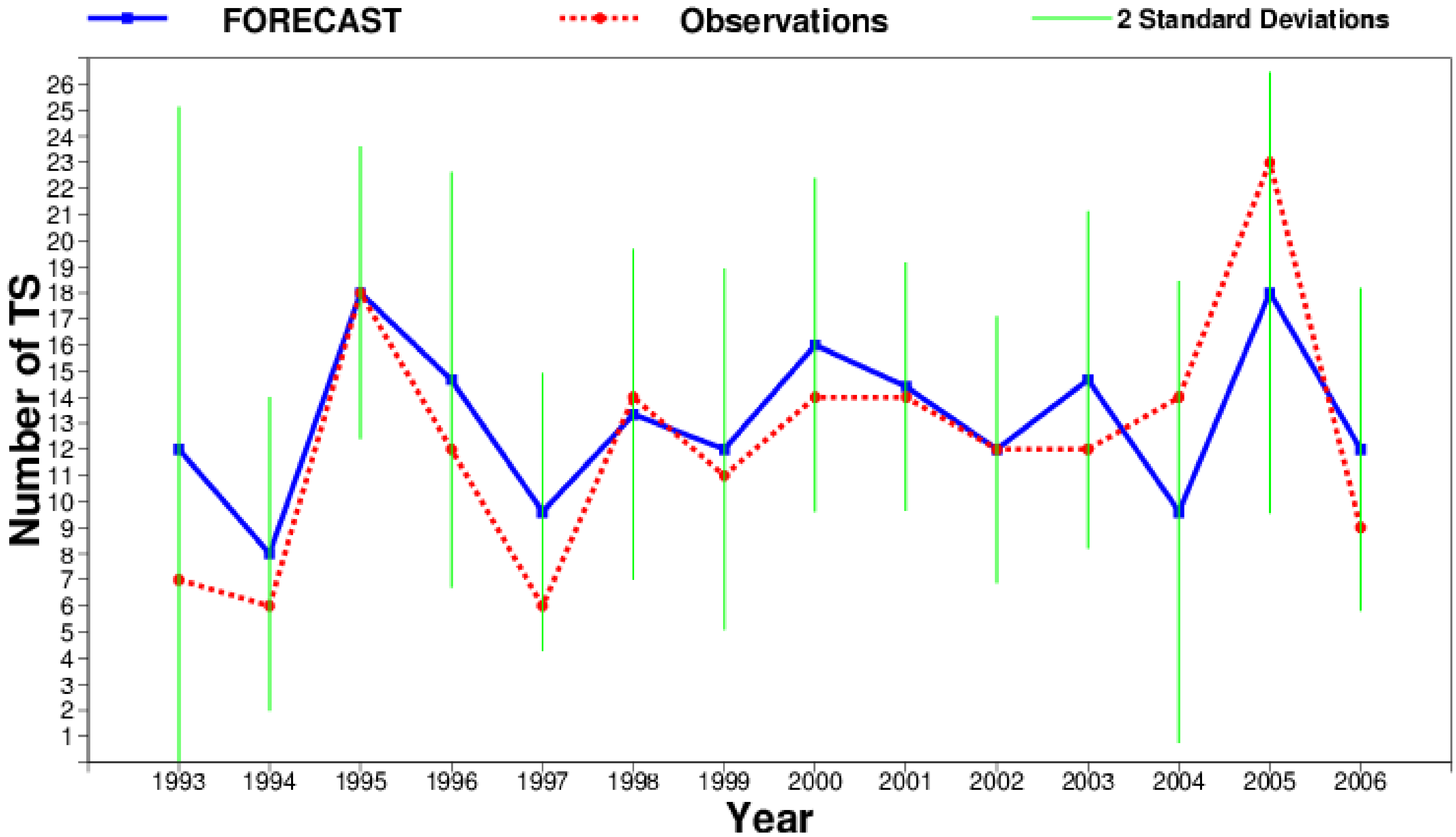
Anomaly Correlation Coefficient for ECMWF with 11 ensemble members
Sea surface temperature
Hindcast period 1981-2005 with start in May average over months 2 to 4
Black dots for values significantly different from zero with 95% confidence (1000 samples)



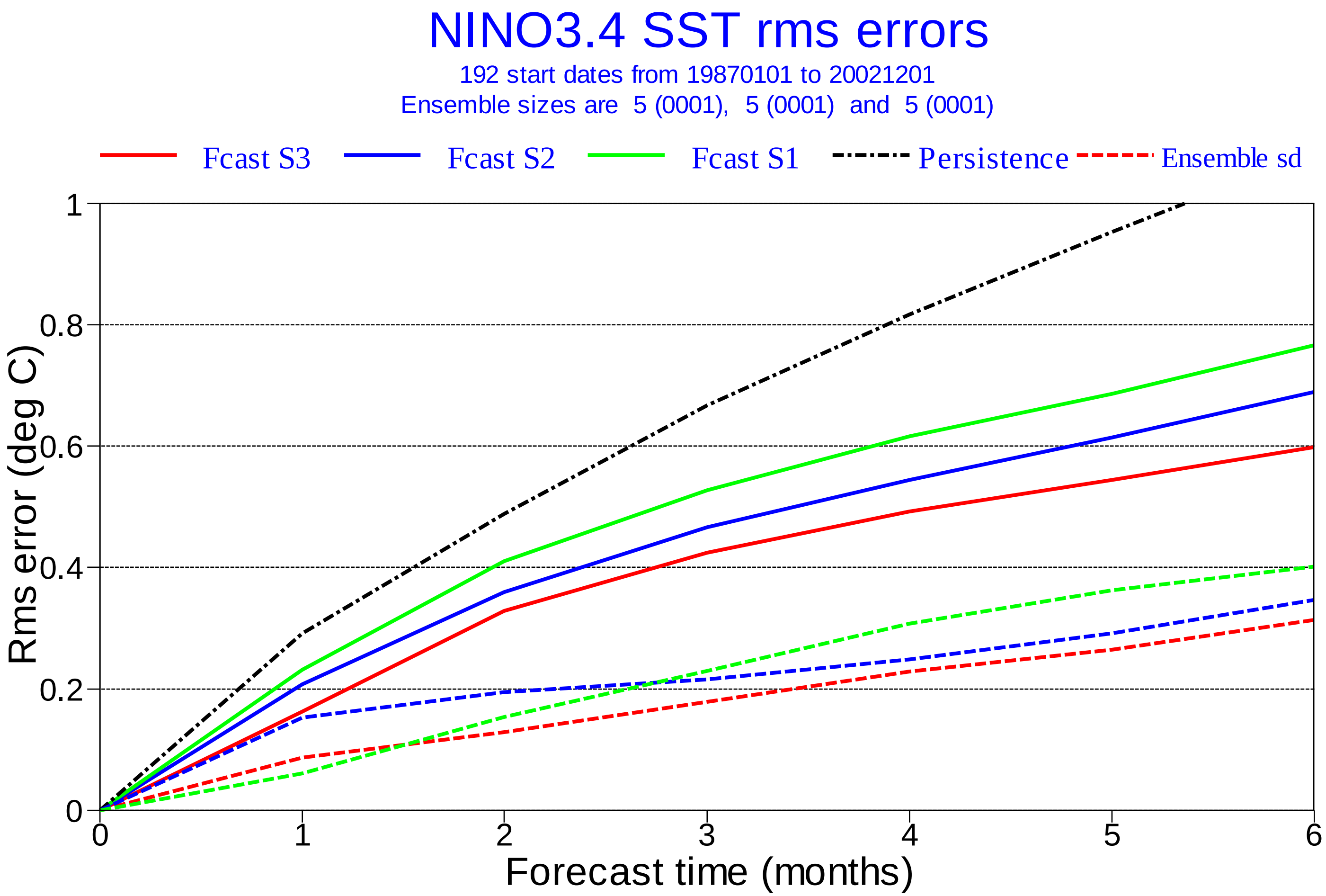
Products from Sys-3 : tropical storm frequency



EUROSIP seasonal fc. of tropical storms (from 1st June)



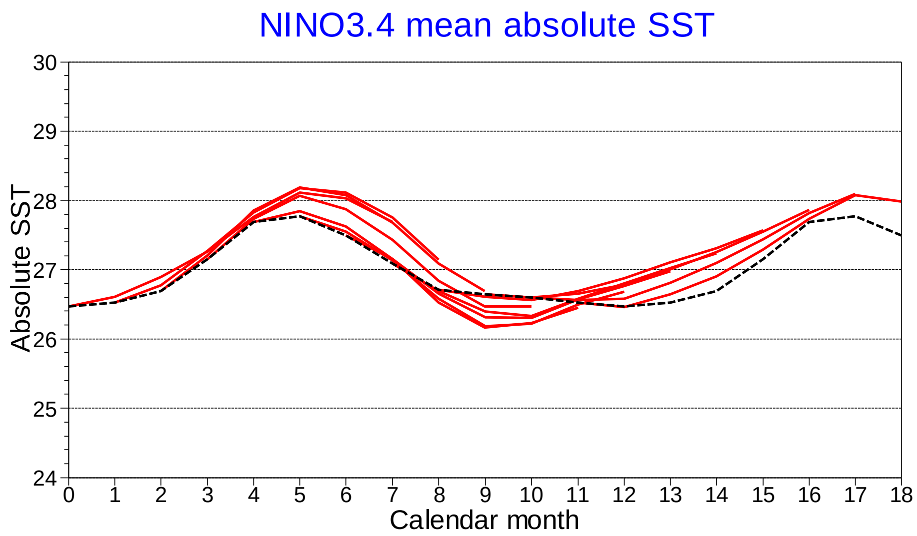
Nino3.4 rms error / spread in different ECMWF systems

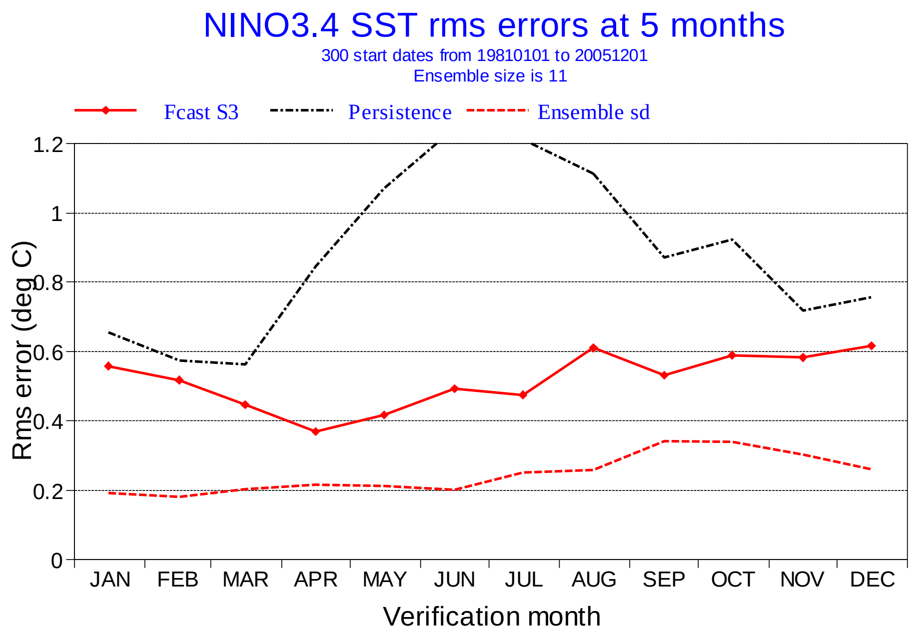


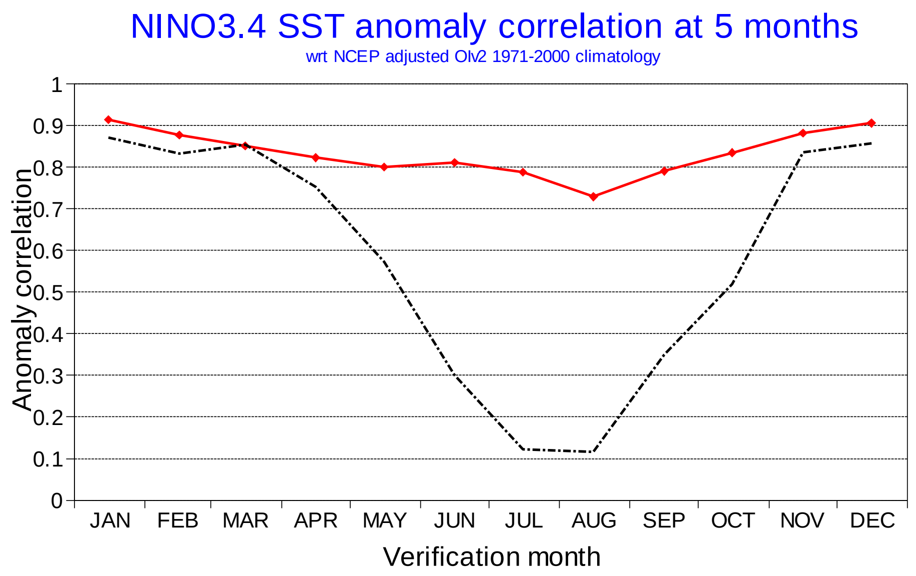
Rms error of forecasts has been systematically reduced (solid lines) ….

.. but ensemble spread (dashed lines) is still substantially less than actual forecast error.

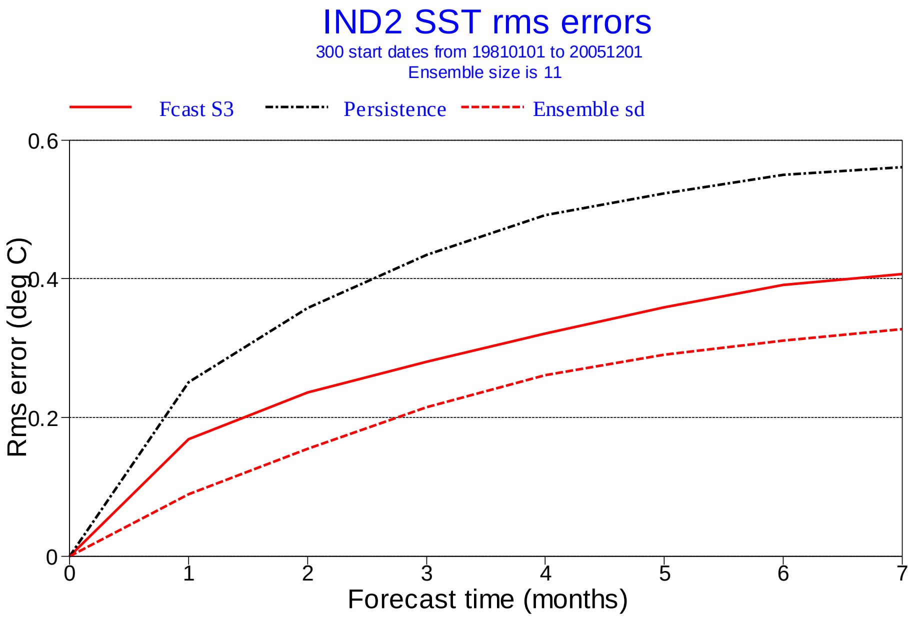
Nino 3.4

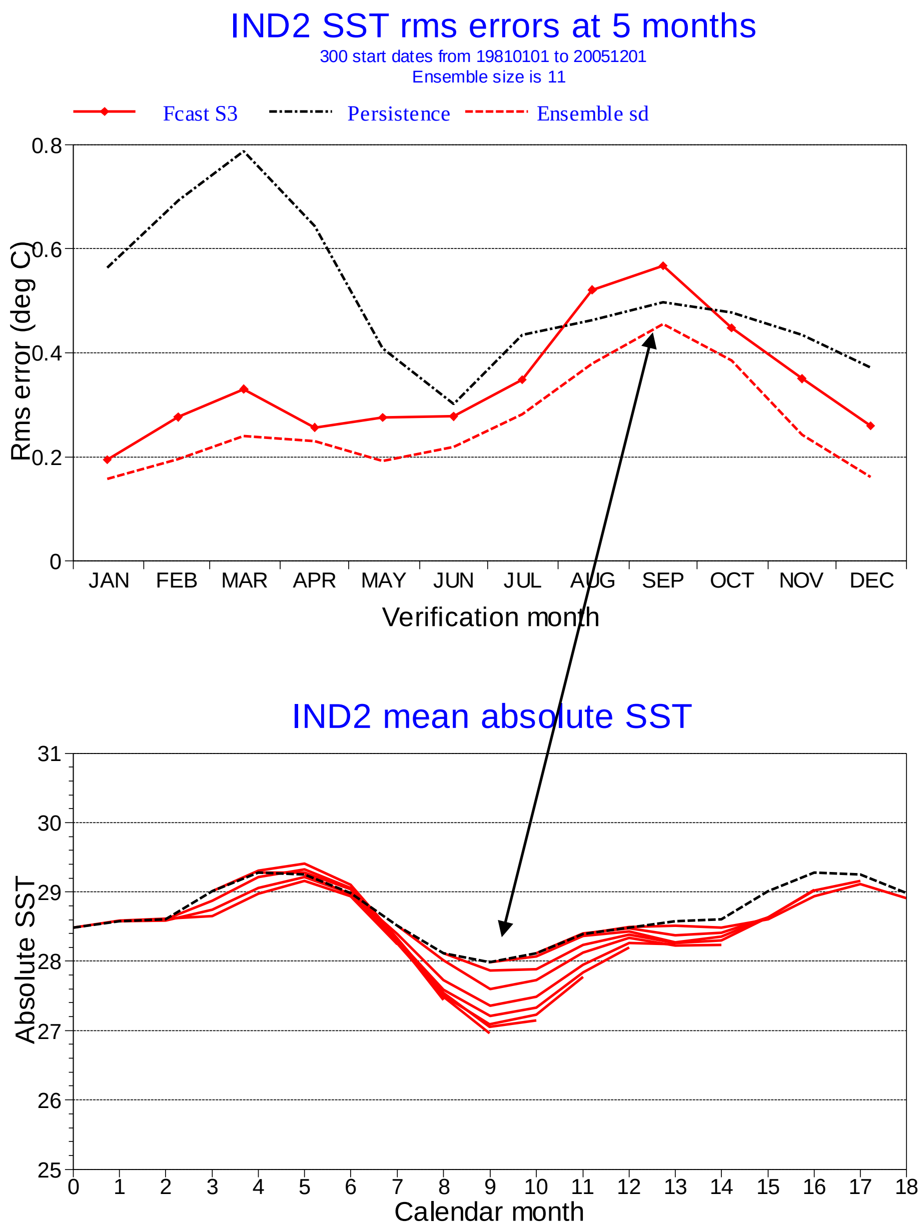

NINO3.4 mean absolute SST
Absolute SST
Calendar month


NINO3.4 SST rms errors at 5 months
300 start dates from 19810101 to 20051201
Ensemble size is 11
Fcast S3
Persistence
Ensemble sd
Rms error (deg C)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Verification month

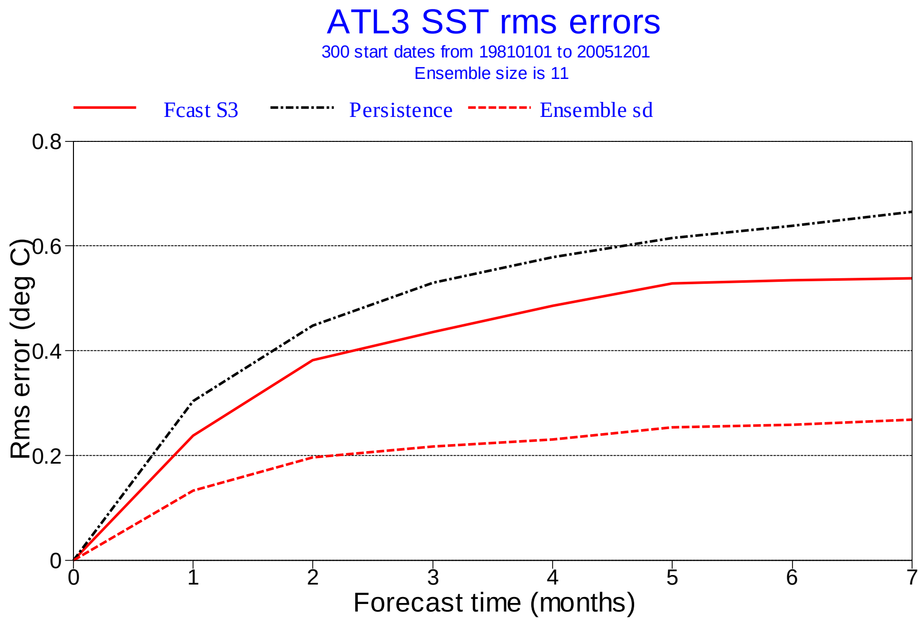

NINO3.4 SST anomaly correlation at 5 months
wrt NCEP adjusted OIv2 1971-2000 climatology
Anomaly correlation
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Verification month

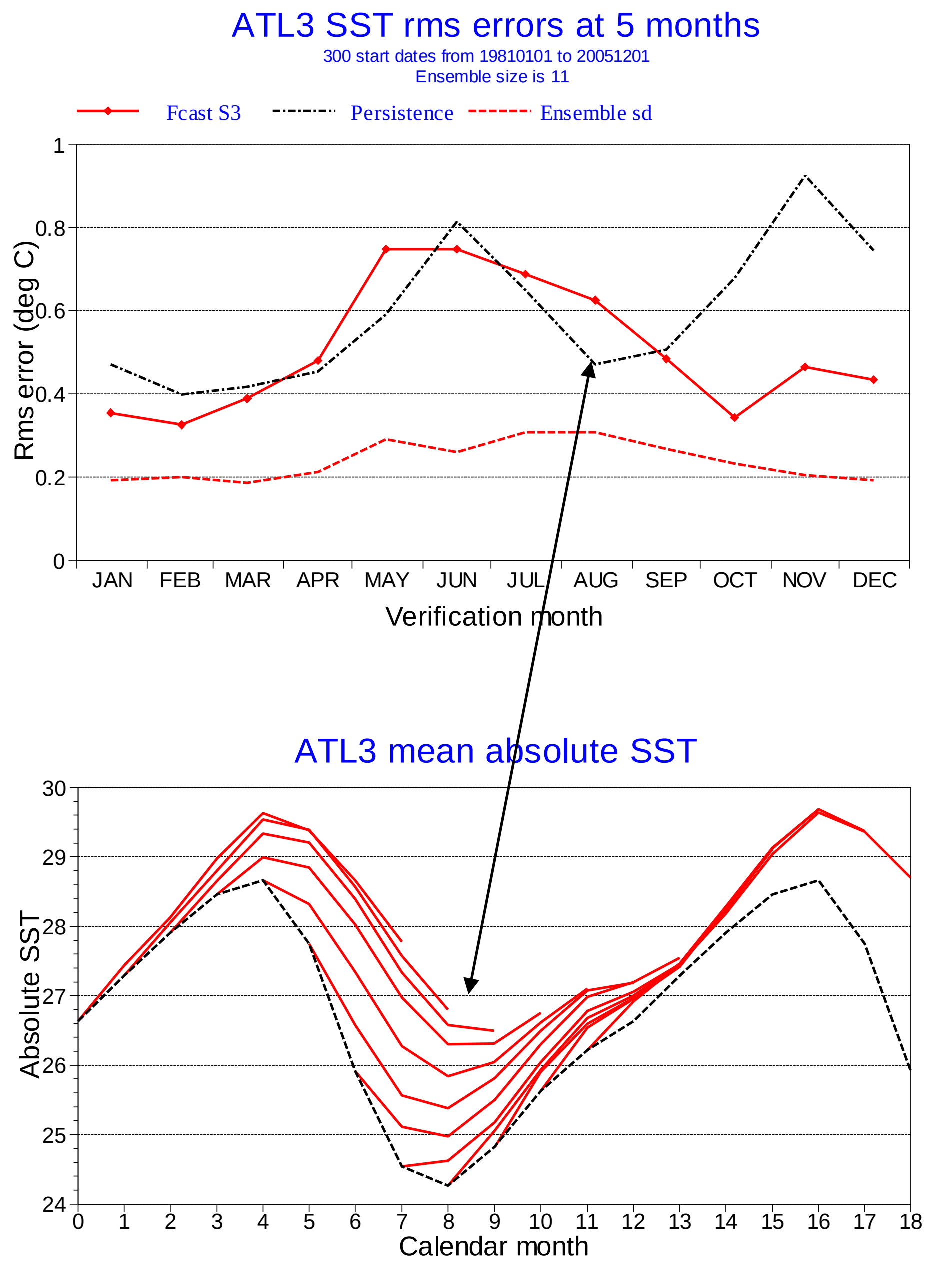
Eastern Indian Ocean





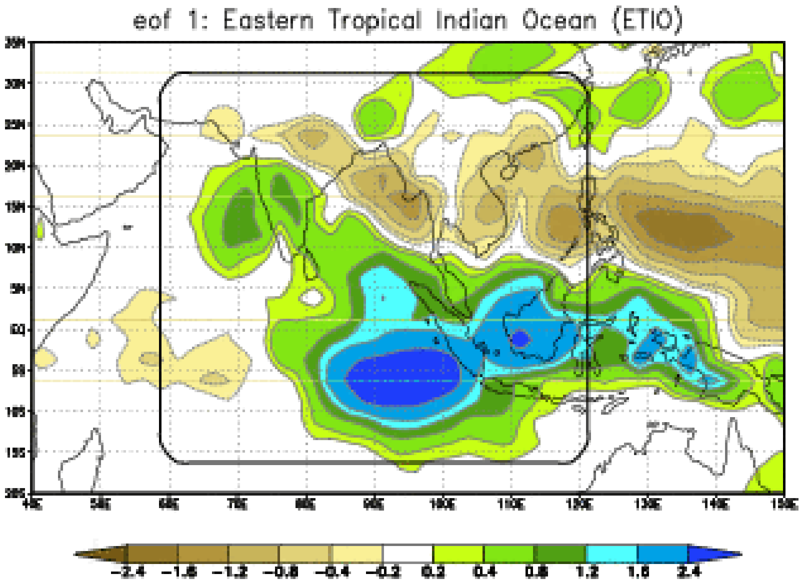
Equatorial Atlantic

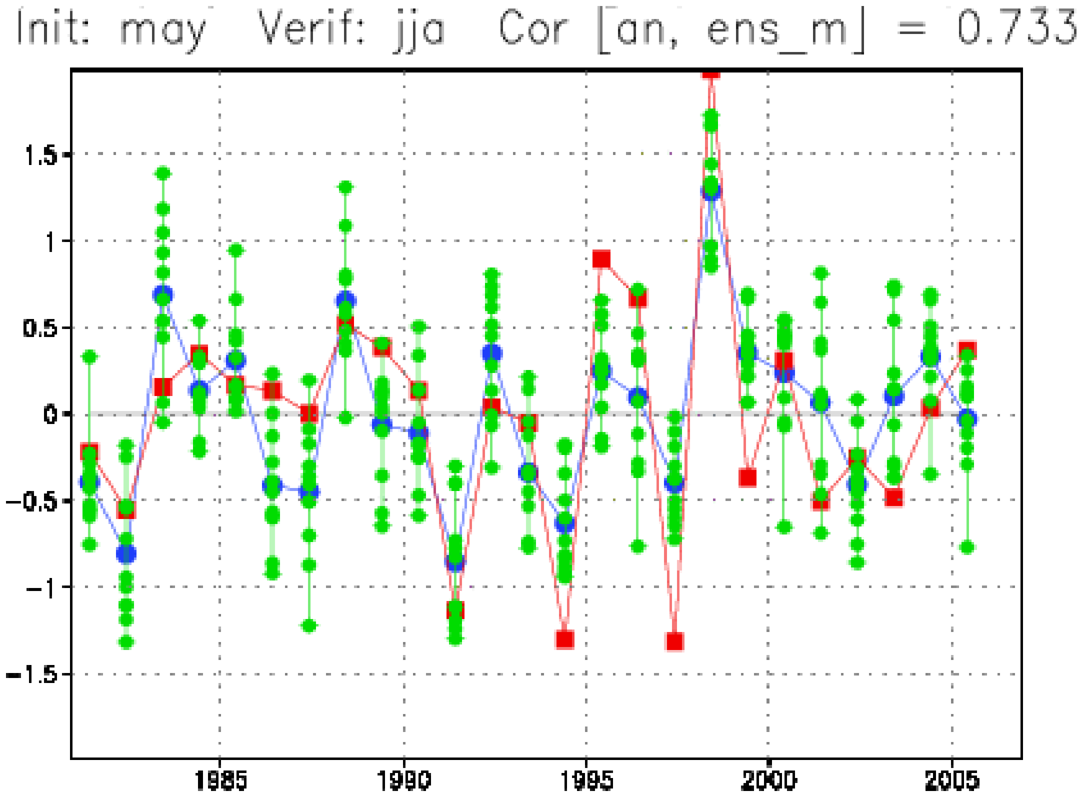




Predictability of teleconnection/EOF indices in S-3

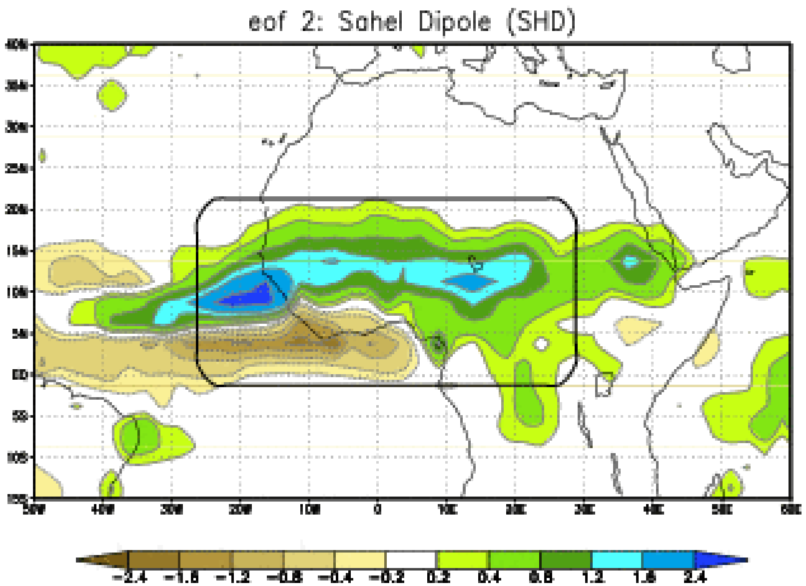
Rainfall: East. Tropical Indian Ocean pattern (JJA)

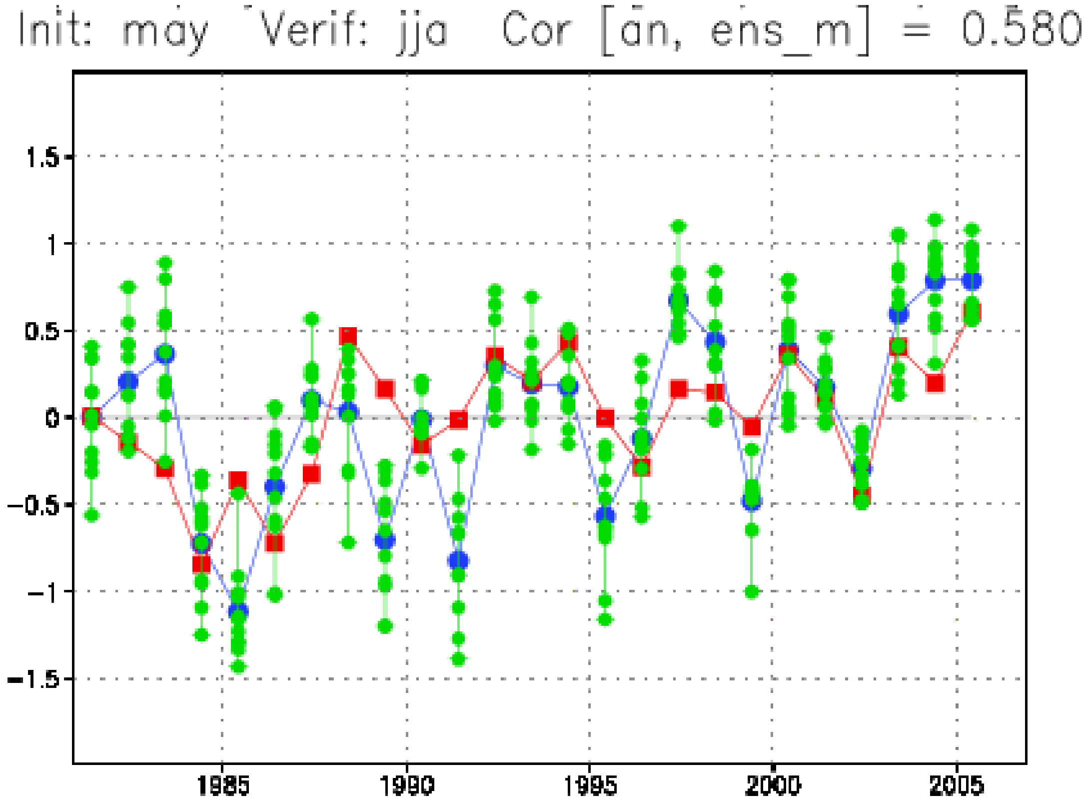




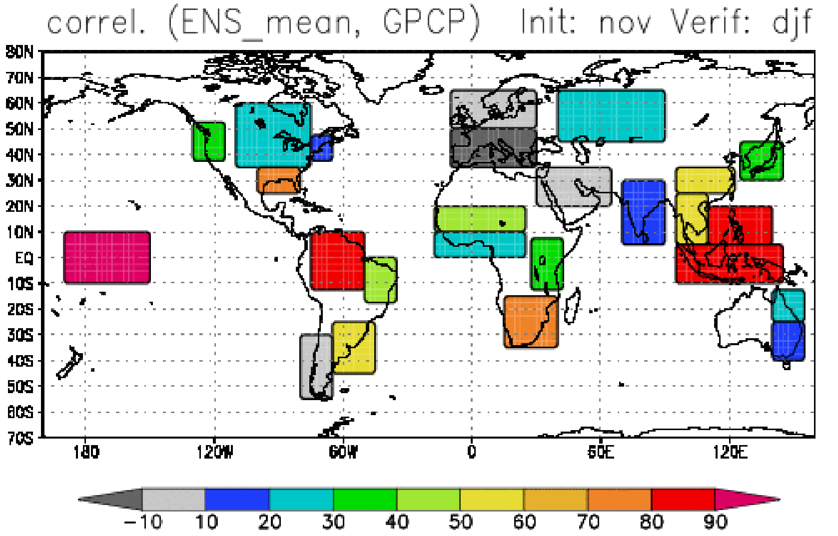
Predictability of teleconnection/EOF indices in S-3

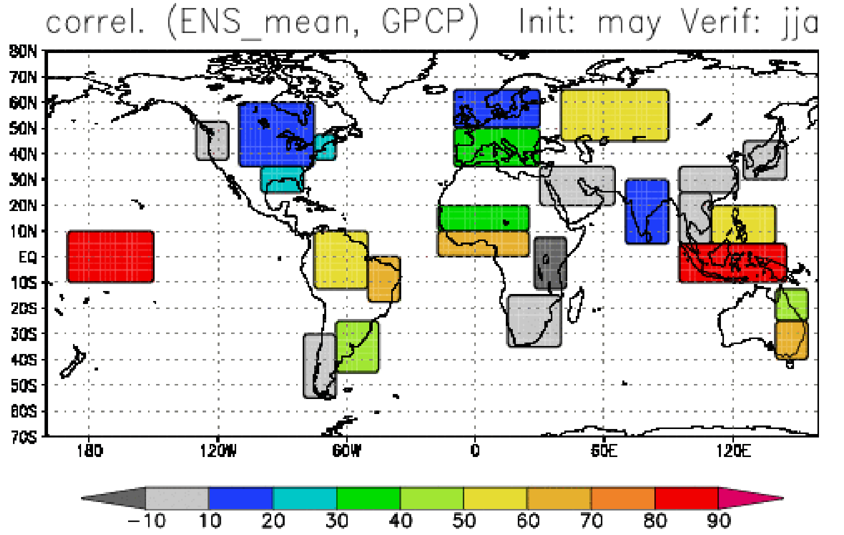
Rainfall: Sahel / Guinea coast dipole (JJA)

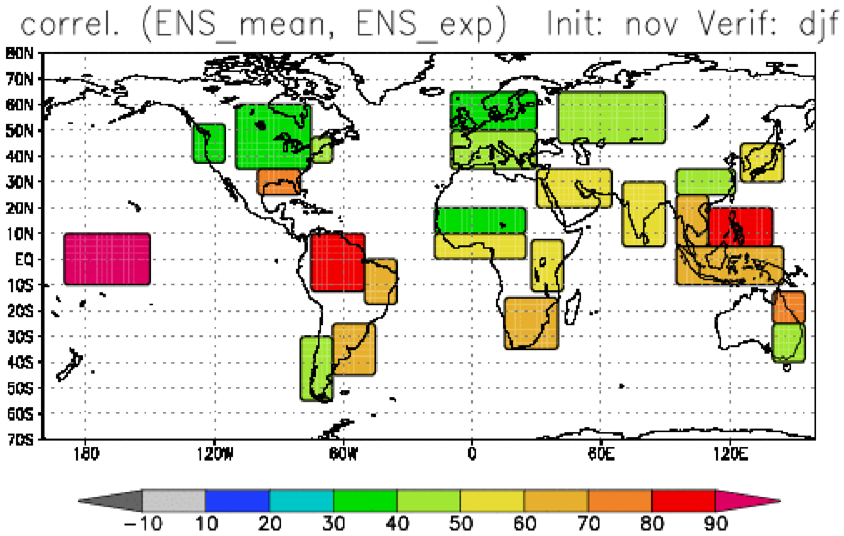


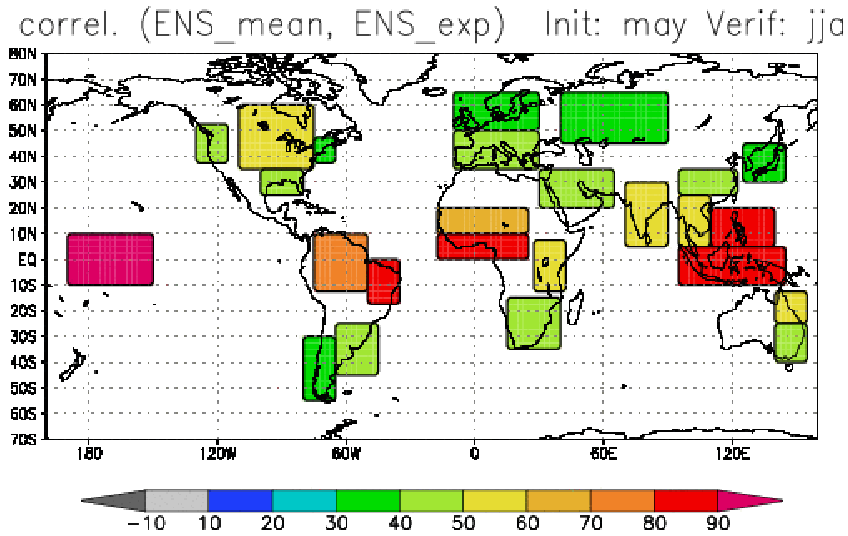


Anomaly correlation of seasonal-mean rainfall

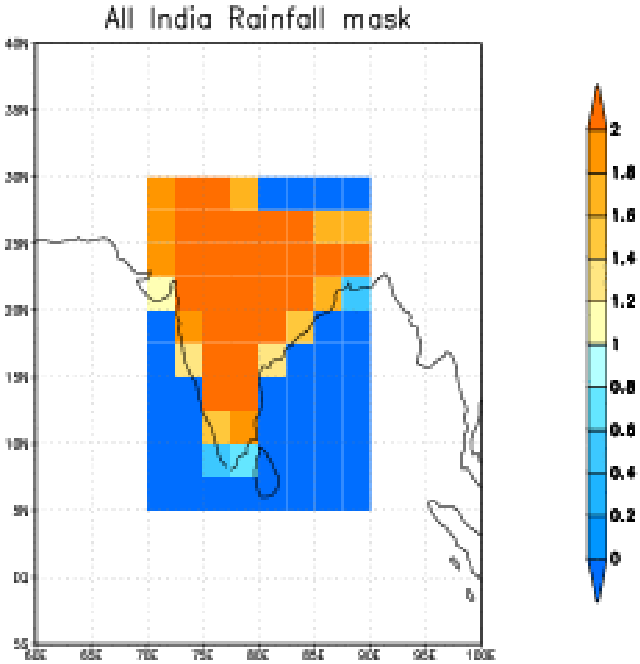






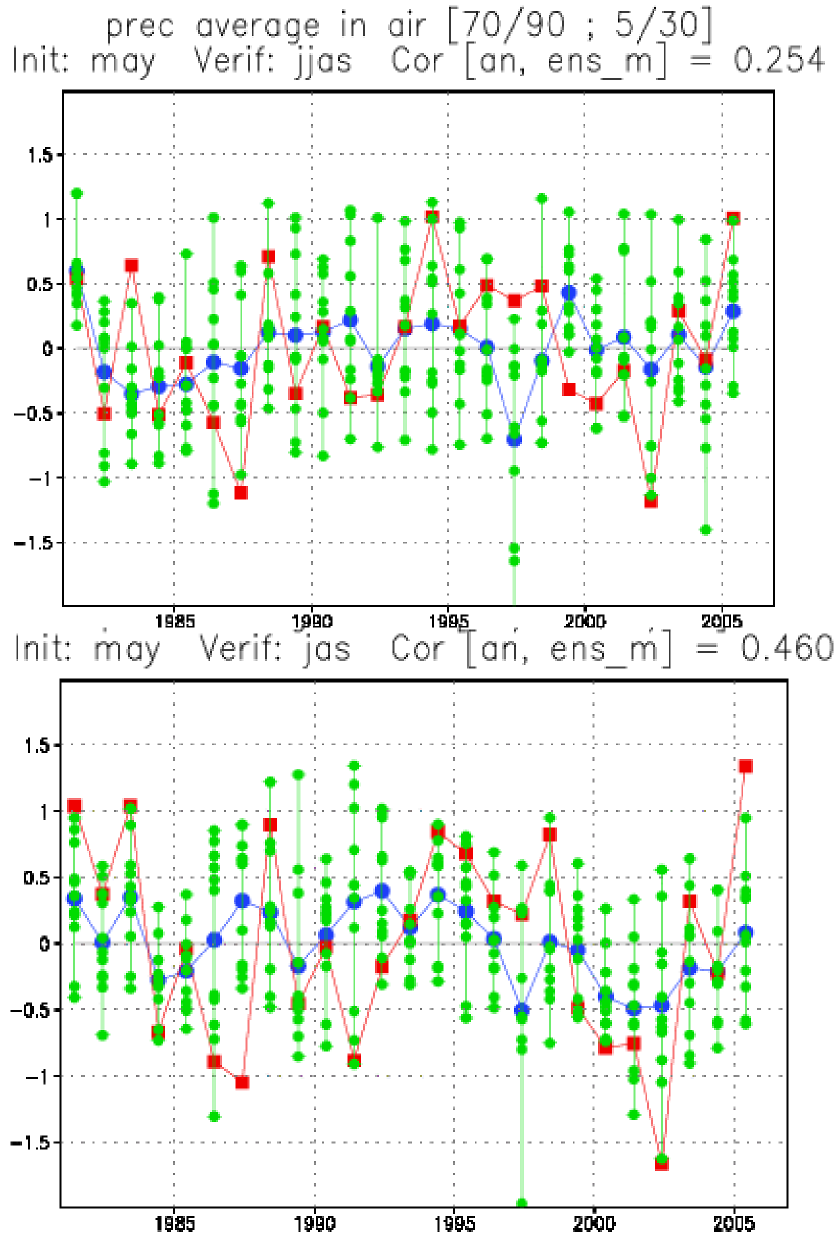


Predictability of AIR in S-3



JJAS
CC = **.25**

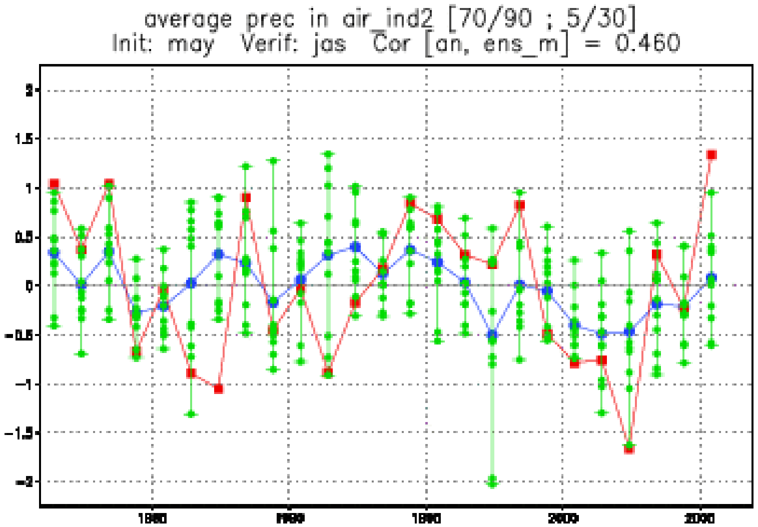
JAS
CC = **.46**

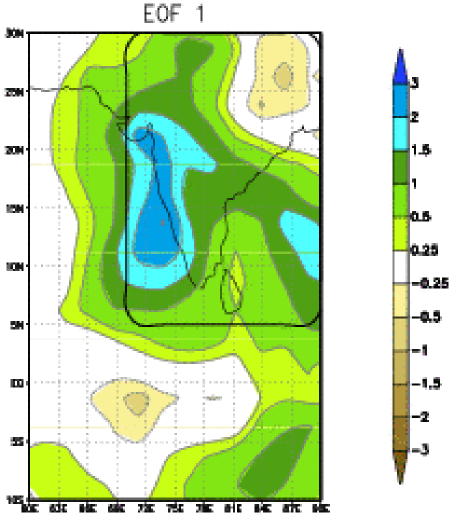


Predictability of AIR in S-3: EOF filtered JAS (2)

Unfiltered

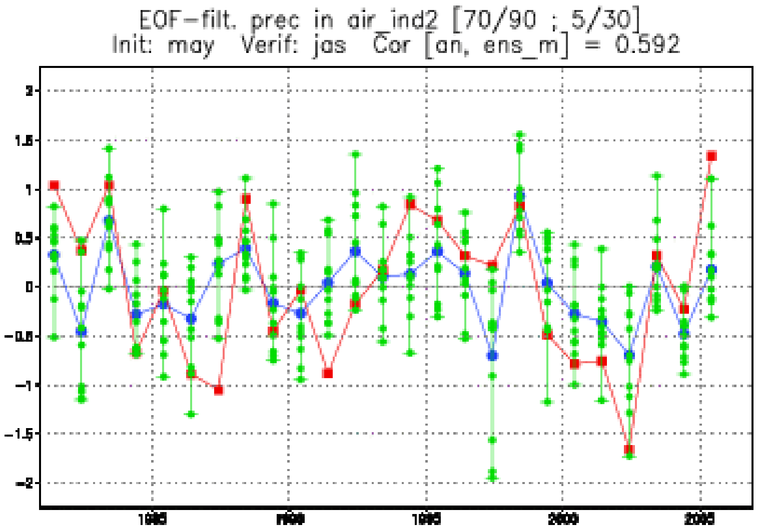
CC = 0.46

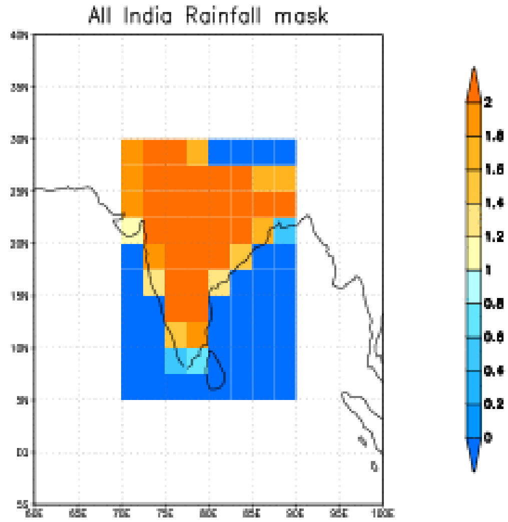




EOF proj.

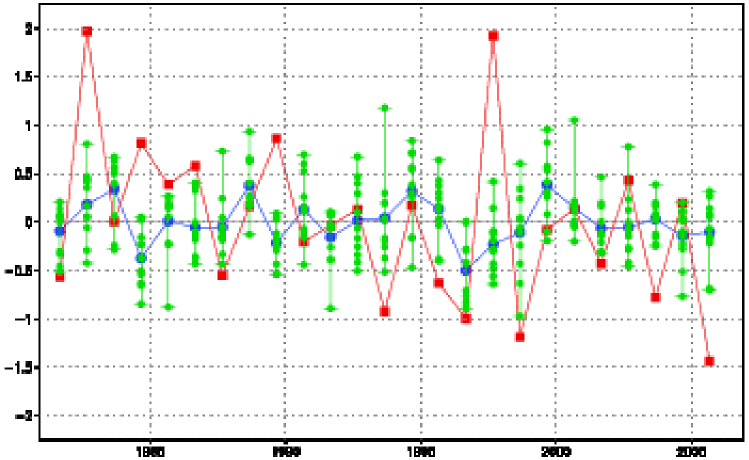
CC = 0.59

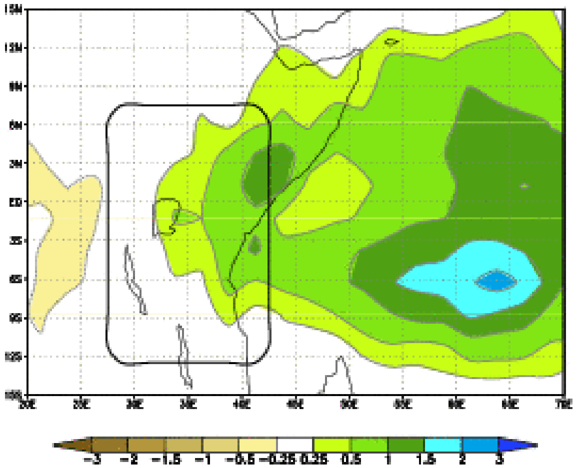




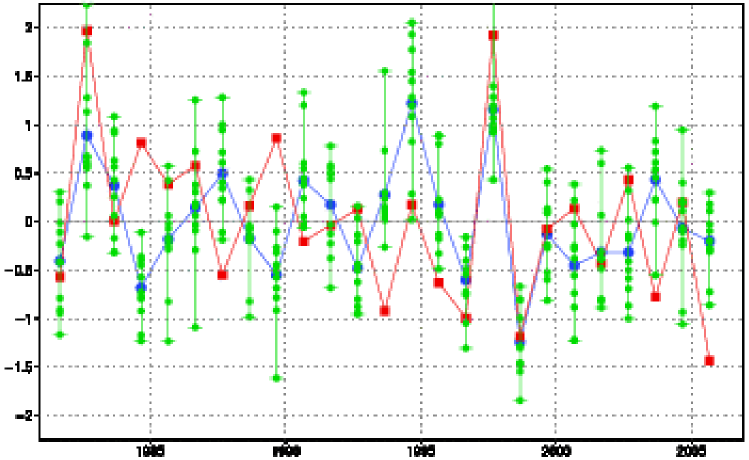
Predictability of East Africa short rains: EOF filtered OND

Unfiltered
CC = 0.04

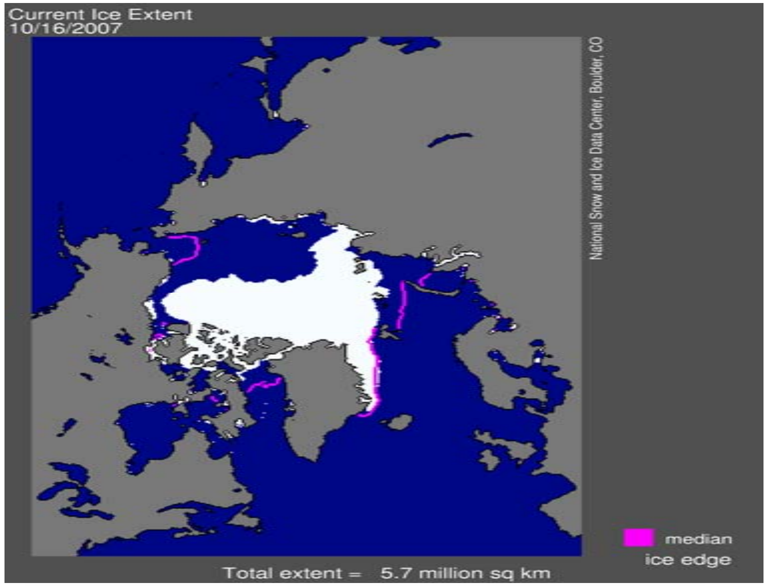


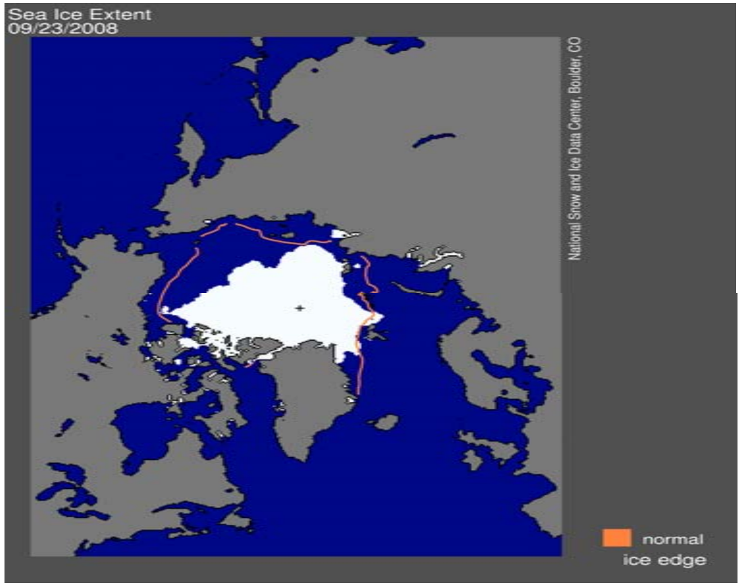


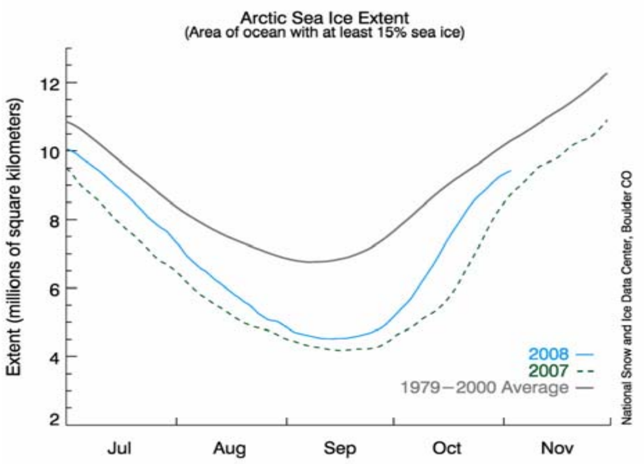
EOF proj.
CC = 0.39



Artic sea-ice variability







- The last 2 summers have seen unprecedented anomalies in the Artic ice extension
- The ECMWF SF system does not represent interannual variations of the sea-ice. Would the SF over Europe improve if artic sea-ice was predicted?

Images from the National Snow and Ice Data Center: http://www.nsidc.org/sotc/sea_ice.html

Sensitivity exp. on response to sea-ice anomalies

1 May - 30Sep 2007 & 2008, 40-m. ensembles

- A1: Sys3 AGCM with prescribed (obs.) SST, observed sea-ice concentration
- A2: Sys3 AGCM with prescribed (obs.) SST, climatological sea-ice concentration
- B1: Sys3 CGCM with predicted SST, observed sea-ice concentration
- B2: Sys3 AGCM with predicted SST, climatological sea-ice concentration

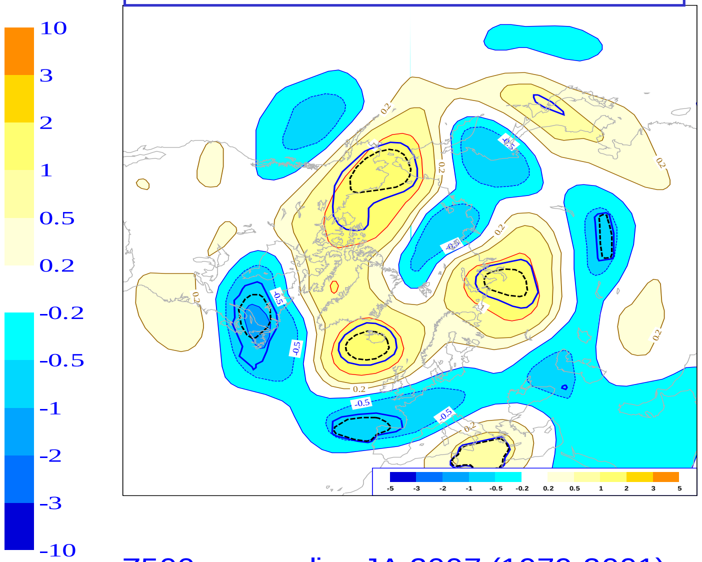
AGCM response : A1 – A2

CGCM response : B1 - B2

Impact on 500 hPa geop. height

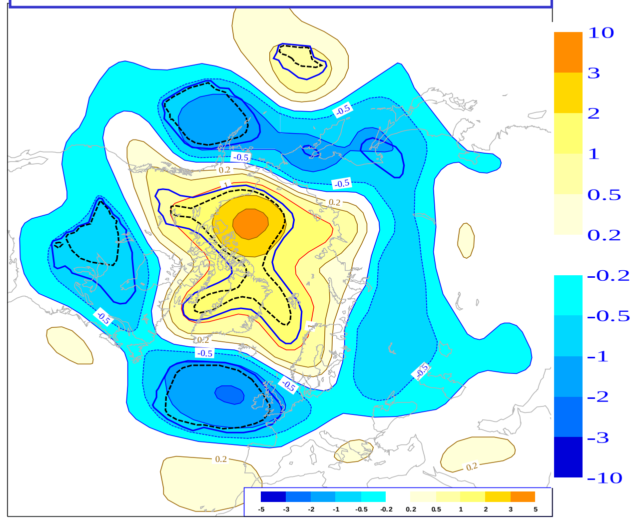
2007

Z500 JA 2007: Obs-Clim Ice



2008

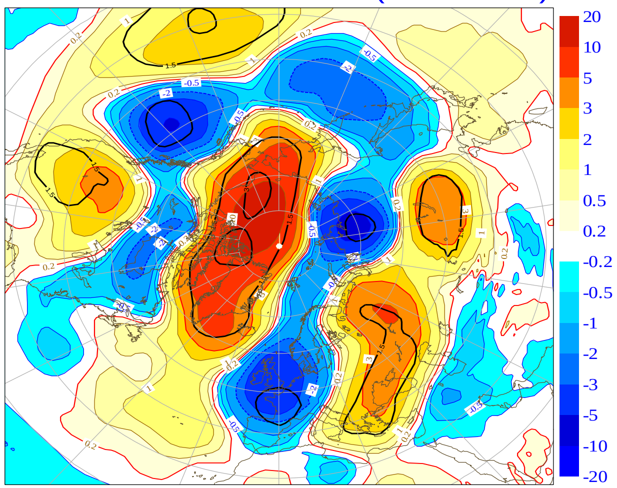
Z500 JA 2008: Obs-Clim Ice



Atmos model

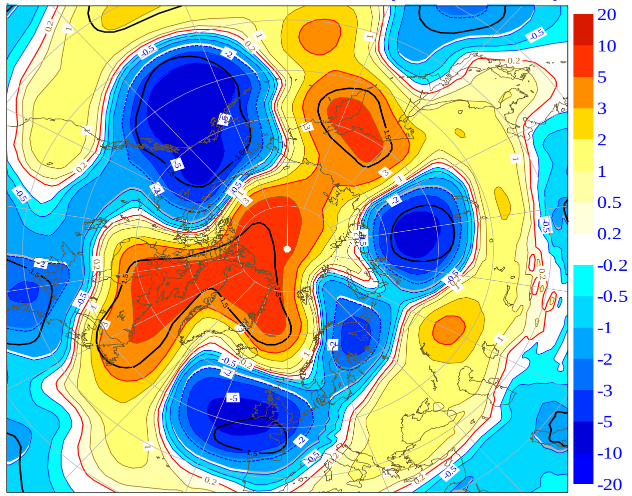
(uncoupled)

Z500 anomalies JA 2007 (1979-2001)



Observed Anomalies

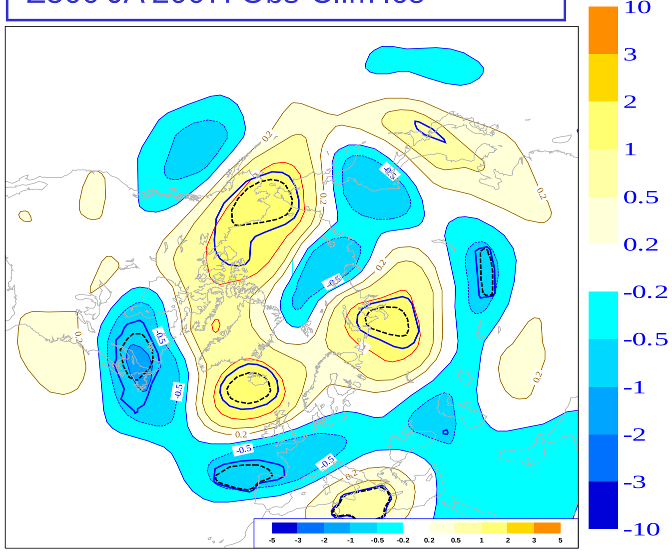
Z 500 anomalies JA 2008 (1979-2001)



But how is the response in coupled mode?

2007

Z500 JA 2007: Obs-Clim Ice

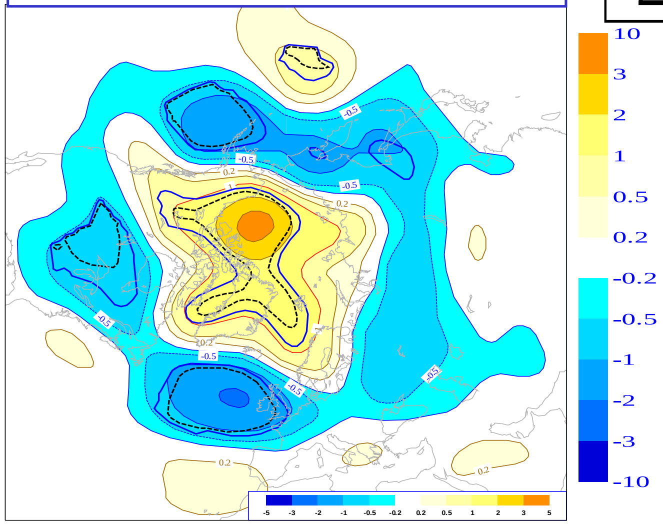


Atmos model

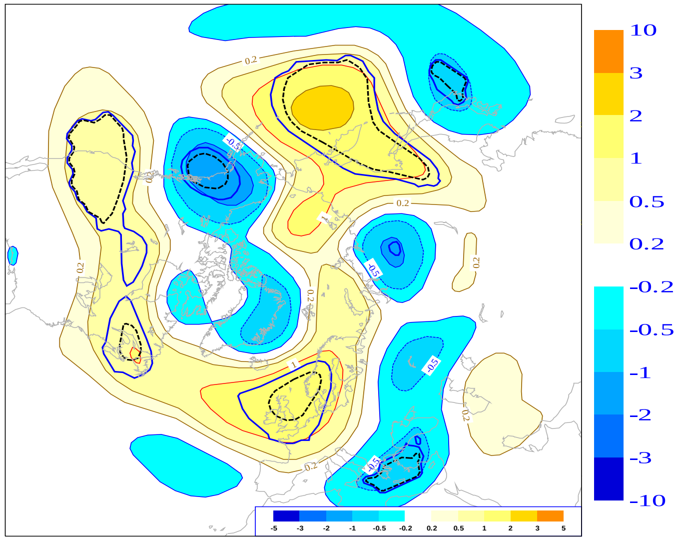
(uncoupled)

Z500 JA 2008: Obs-Clim Ice

2008



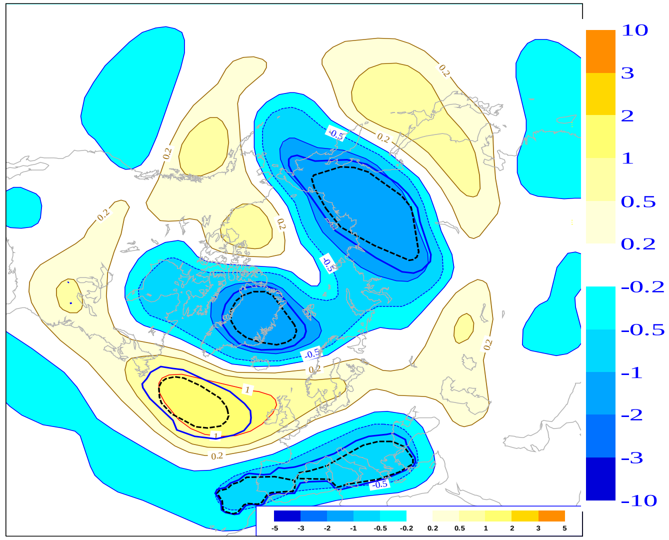
Z sensitivity: Obs-Clim JA 2008



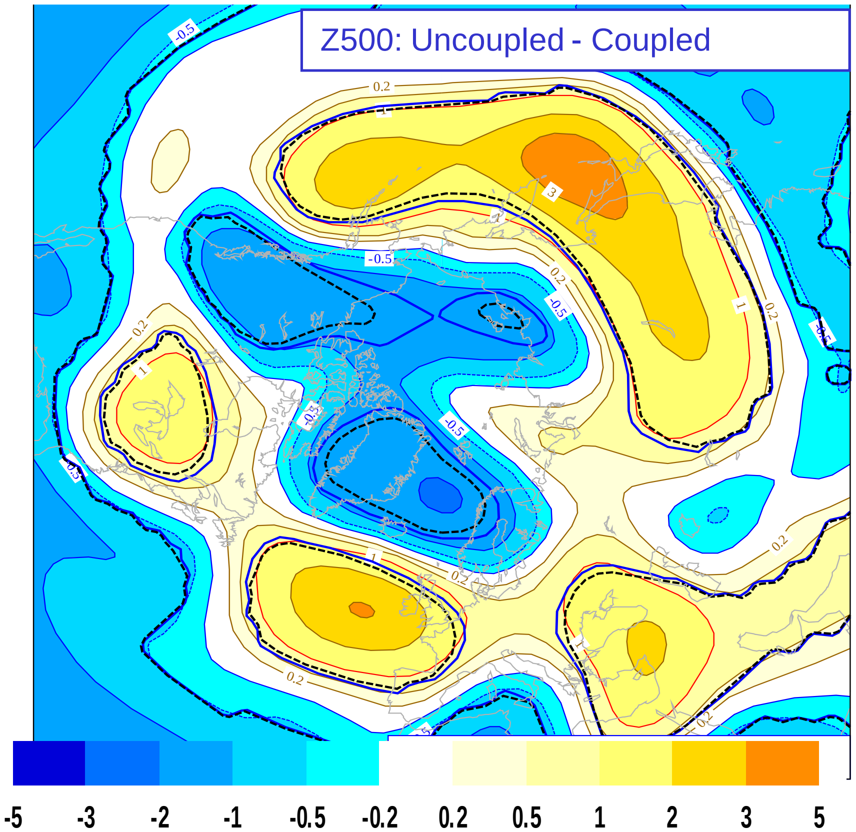
Coupled

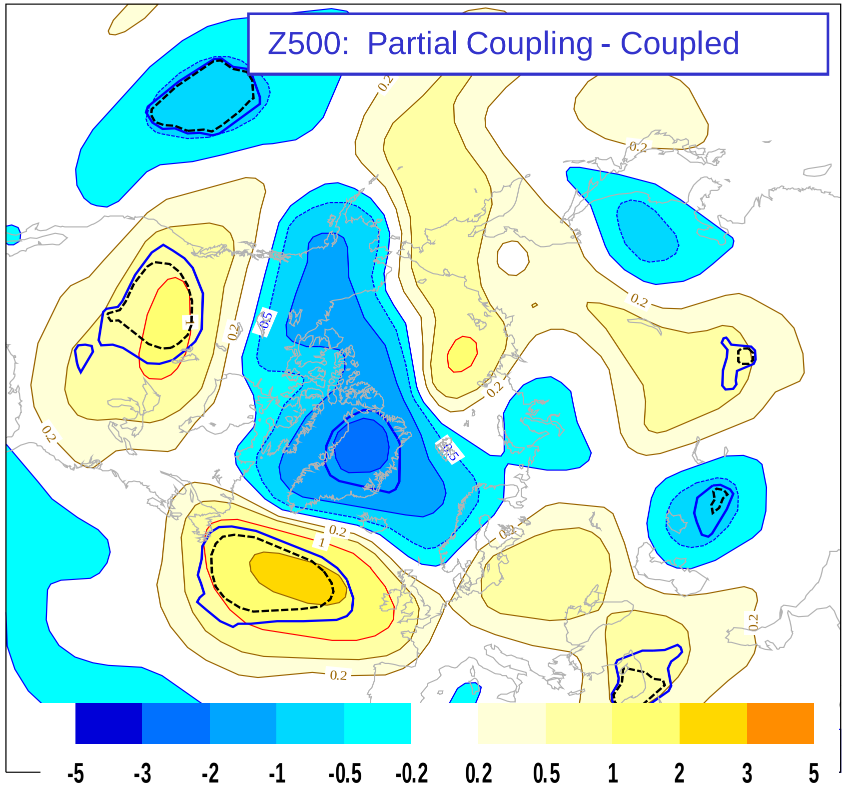
model

Z sensitivity: Obs-Clim JA 2008



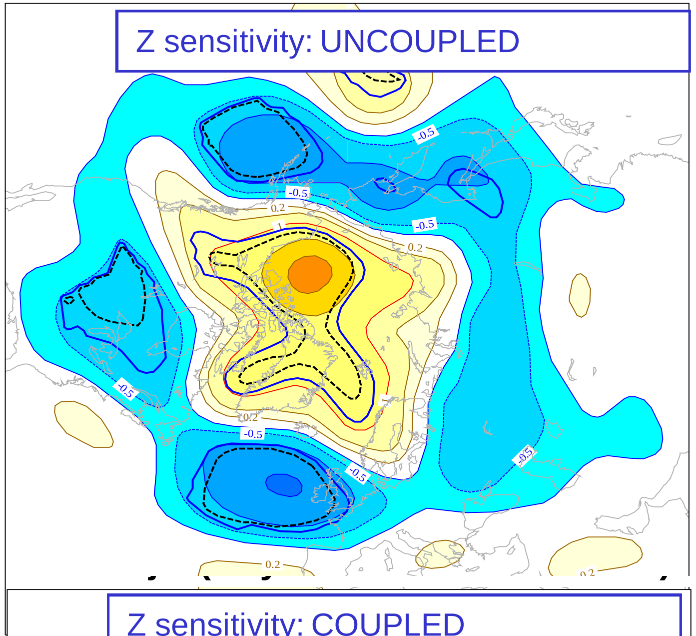
Impact of SST bias in the Gulf Stream region

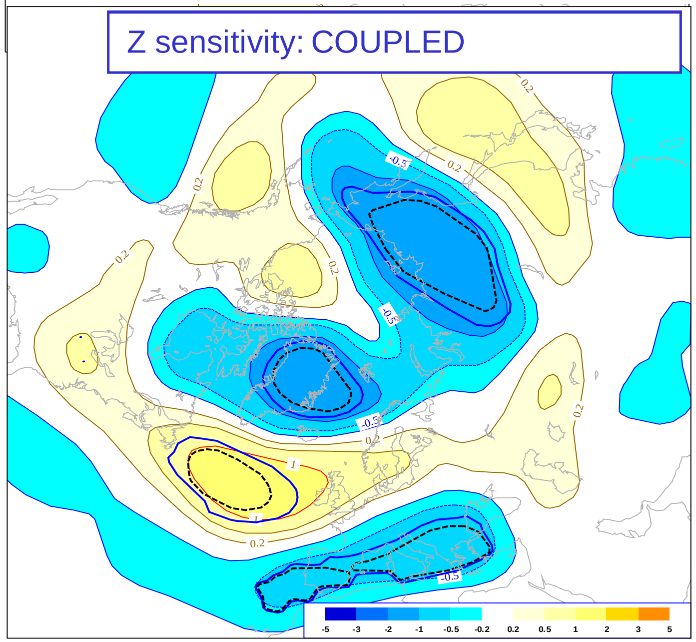


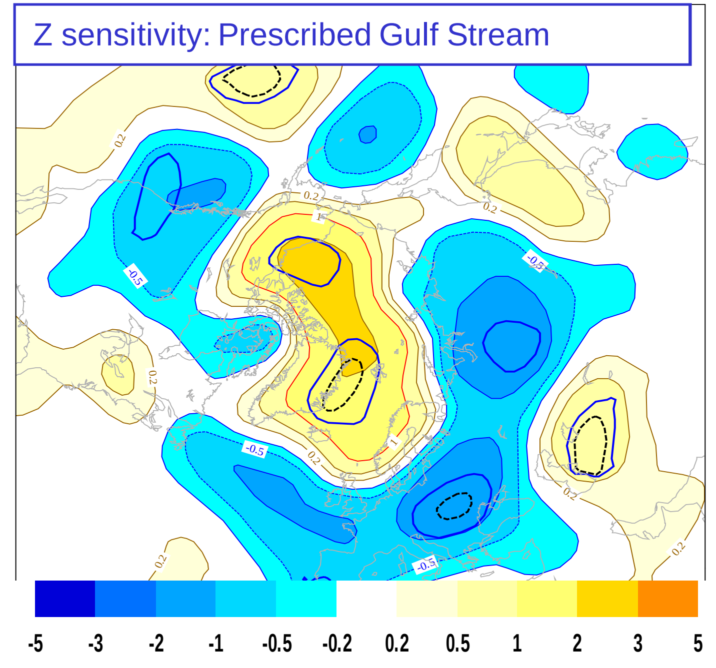


SST bias in the Gulf Stream region may explain a large part of the cupled model systematic errors over the North Atlantic Sector

Impact on the response to the Arctic Ice anomaly







Correcting the SST bias in the Gulf Stream region changes the atmospheric response to the prescribed sea-ice anomaly

Conclusions (1)

- SST predictions from the ECMWF seasonal forecast system-3 show higher skill than those from previous system, particularly in the tropical Pacific and eastern Indian Oc., but western Indian Oc. and tropical Atlantic are still not better than persistence in NH summer.
- Predictive skill for seasonal rainfall is generally good over the Pacific and tropical S. America, poor along the coast of the Indian Ocean in early summer. Skill for South Asian rainfall increases in the latter part of the monsoon season.
- Substantial model errors affect rainfall variability over tropical land; however, rainfall forecasts over land can be improved by exploiting teleconnections with adjacent ocean regions.

Conclusions (2)

- In the Arctic and North Atlantic regions, signals associated with interdecadal variability (natural and/or anthropogenic) are increasingly affecting anomalies on seasonal time-scale.
- Experiments with ECMWF Sys3 suggest a positive feedback between recent summertime reduction in sea-ice extent and AO/NAO-like circulation anomalies.
- If results from EPS-monthly and seasonal forecast systems are used on the appropriate scales, and minimal amount of statistical post-processing is performed to correct model biases, dynamical predictions from the ECMWF systems can be used into provide skilful, seamless information on atmospheric variability over a number of tropical and extra-tropical regions.